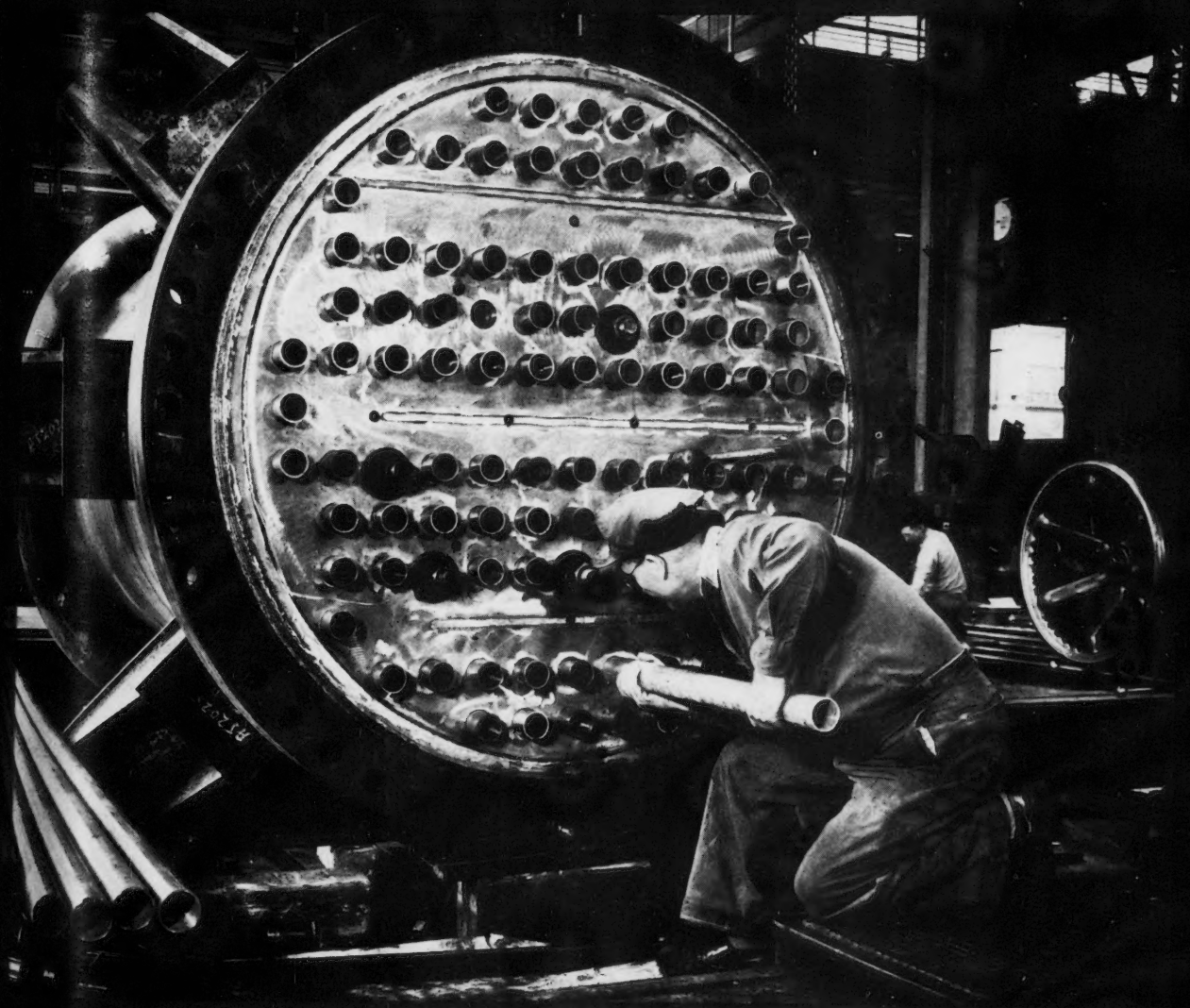
Corrosion



JUNE 1955

to

CONTROL CORROSION

where only

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is possible

use the

Amercoat 33 over 86 System

There is no substitute for ideal surface preparation. But every maintenance engineer is confronted with corrosion problems in locations where only minimum surface preparation is possible. The Amercoat 33/86 System is amazingly helpful in many of these cases. Here is how it works:

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An Entirely New Low Cost All-Purpose Detector

Tinker & Rasor

MODEL E-4 DETECTOR

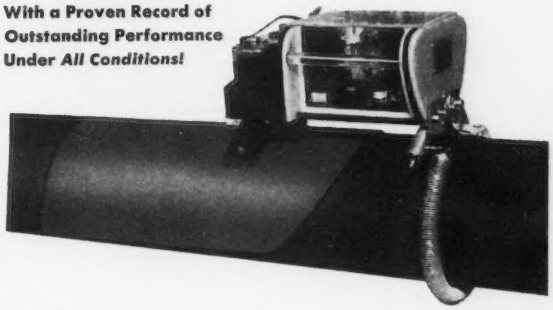
- Lightweight
- D. C. Output
- Shock Proof Case
- Adjustable Voltage
- Non-Destructible Type Material

The Model E-4 Detector is a portable instrument designed for both large and small pipe. It features direct current, high potential output, accurate bell signal alarm, and is adaptable to both the full circle and half circle electrodes. It is adjustable from 2500 to 20,000 volts D. C. and offers a shock proof, non-destructible type case.

HOLIDAY DETECTOR

Tinker & Rasor MODEL H-2

The Holiday Detector With a Proven Record of Outstanding Performance Under *All Conditions!*



- The detector that maintains a constant potential on the pipe because it is the only detector with the Double Electrode System (Pat. Pending).
- The only Holiday Detector that operates without a ground wire.
- Extremely short pulse duration (less than 2 micro-seconds at crest) provides assurance of minimum dielectric stress on coatings.
- Maintains constant potential on wet coatings.
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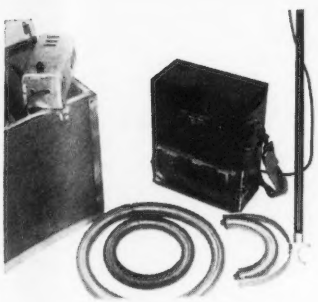

Tinker & Rasor

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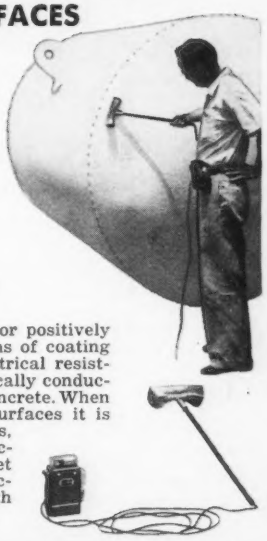
- Rechargeable Battery
- Bell Signal
- D. C. Output
- High-Low Voltage
- Lucite Case
- Portable Operation

The Model DS-3 Portable Holiday Detector is an all-purpose instrument designed for both small and large pipe diameters and features direct current high potential output, accurate bell signal alarm and variable voltage adjustment. It is adaptable to half-circle electrodes from 2 to 8 inches in diameter and full-circle electrodes from 4 inches to 30 inches in diameter. It also features a rheostat to vary terminal output from 5,000 to 20,000 volts d.c. which may be adjusted by a recessed adjusting screw. The case is constructed of ⅜" lucite, thereby practically eliminating shock hazard.

NEW ELECTRICAL DEVICE FOR INSPECTING THIN FILMS ON CONDUCTIVE SURFACES

Tinker & Rasor

MODEL M-1 DETECTOR



- Non-Destructive
- Accurate
- Bell Signal
- Light Weight (4 lbs.)

The new Model M-1 Detector positively and accurately checks thin films of coating material which have high electrical resistance when applied to an electrically conductive surface such as metal or concrete. When used on brushed or sprayed surfaces it is possible to detect pin holes, voids, and bare spots. Maximum inspection voltage — 68 volts d. c. Set consists of cellulose sponge electrode wand, electrical unit with batteries and 15′ ground wire.

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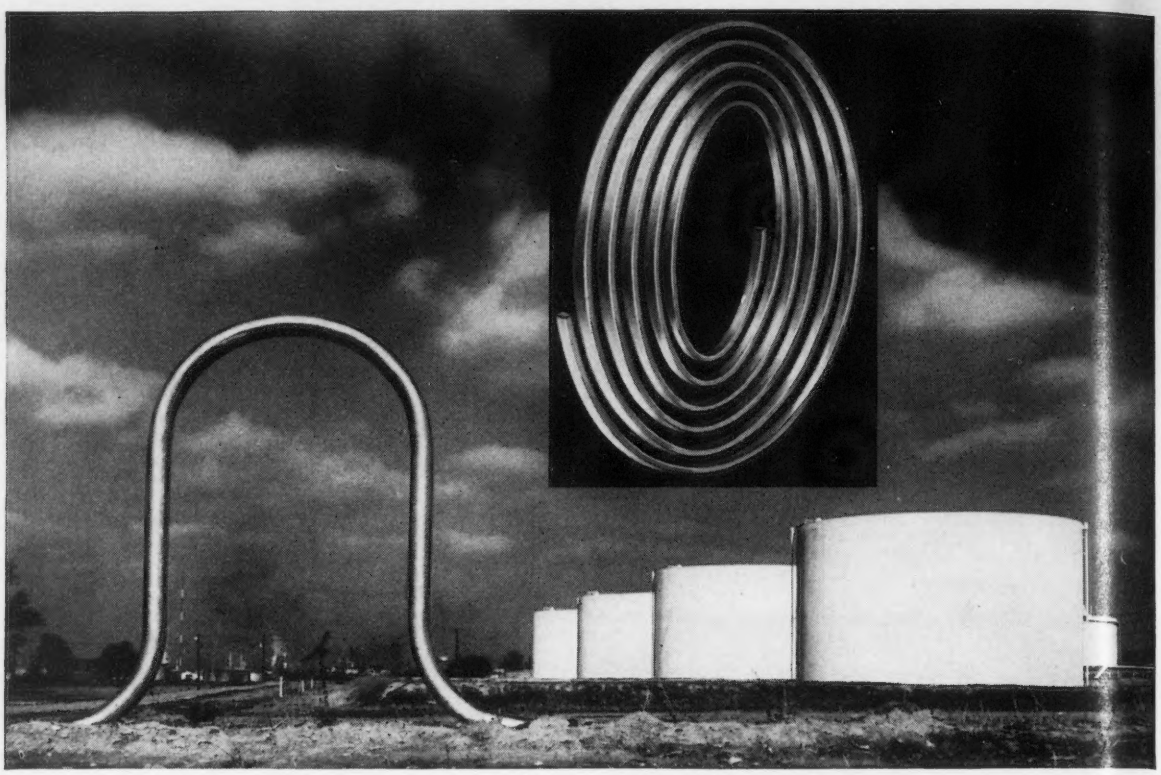

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When considering galvanic protection, think first of Galvo-Line®—the most economical method of pipeline protection—unique for its fast, mechanized installation.

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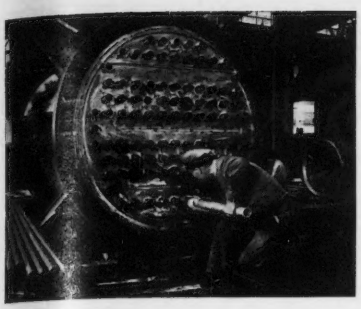

THIS MONTH'S COVER—Hastelloy B tubing is being installed here at the plant of Nooter Corp., St. Louis. The 9¼ inch thick steel tube sheets were faced with Hastelloy B as were the headers of this heat exchanger. The whole unit weighed 26 tons. Modern chemical processes increasingly require high alloy materials for adequate corrosion resistance.

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Foreign remittances should be by international postal or express money order or bank draft negotiable in the U. S. for an equivalent amount in U. S. funds. Entered as second class matter October 31, 1946, at the Post Office at Houston, Texas, under the act of March 3, 1879.

CORROSION is Indexed Regularly by Engineering Index.

CORROSION

devoted entirely to corrosion research and control

Published Monthly as its official journal, by the National Association of Corrosion Engineers, Inc., at Houston, Texas, U. S. A., as a permanent record of progress in corrosion control.

Vol. 11 — June, 1955 — No. 6

CONTENTS

Page

Directory of NACE Regional and Sectional Officers 4-6
Officers and Directors, National Association of Corrosion Engineers 16

TECHNICAL SECTION

Topic of the Month—Atmospheric Corrosion of Mild Steel in a Chemical Plant
By Robert I. Zimmerer 17

Placing Ground Contact Anodes With a High Velocity Water Jet
By Walter P. Noser 18

Acid Corrosion Inhibition by High Molecular Weight Nitrogen-Containing Compounds
By Raymond A. George and Norman Hackerman 19
Discussion: A. H. Roebuck; Reply by Norman Hackerman, Page 23.

An Automatic Circuit Interrupter for Use in Cathodic Protection System Design
By L. Schwalm 24

Use of the Pearson Bridge in Corrosion Inhibitor Evaluation
By E. J. Simmons 24

Control of Internal Corrosion of a Products Pipe Line System
By P. L. DeVerter and A. W. Jasek 31
Discussion: R. S. Treseder, Page 35; Ivy M. Parker, Page 36; Replies by P. L. DeVerter, Pages 35, 36.

Corrosion Studies on a Modern Rotary Air Pre-Heater
By G. G. Thurlow 37
Discussion: U. Blomquist, J. H. G. Carlile, Page 42; H. M. L. Coward, Page 43; Reply by G. G. Thurlow, Page 44.

Discussions: Proposed Standard Laboratory Procedure for Screening Corrosion Inhibitors for Use in Oil and Gas Wells; A. H. Roebuck, John R. Gilcrease, R. S. Treseder, Loyd W. Jones, Jerome Green; Replies by J. C. Spalding, Jr., Page 45.
Electrical Measurements Applied to Corrosion Investigations: Reply by William R. Schneider and David Hendrickson, Page 46.

Reports to Technical Unit Committee T-1J on Oilfield Structural Plastics. Part 1—Long-Term Creep of Pipe Extruded from Tenite Butyrate Plastic. Part 2—Structural Behavior of Unplasticized Geon Polyvinyl Chloride. Publication 55-7 47

TECHNICAL COMMITTEE ACTIVITIES

Page

Summary of Data on Use of Structural Plastic Products in Oil Production. A Status Report of NACE Technical Committee T-1J on Oilfield Structural Plastics 59

Tentative Procedures for Preparing Tank Car Interiors for Lining. A Report by NACE Task Group T-3E-1 on Corrosion Control of Railroad Tank Cars 69

Page

Data to Complete Sour Oil Well Report Gathered 70
Reports on Plastic Coatings Circulated 70
Coburn Is Vice-Chairman of Committees 72
Technical Committee Officers Elected 74
Organization of T-6A Revised 74
Report to be Distributed 74
T-2C-1 Is Reorganized 74
One-Day Painting Application Course Held 76
Cathodic Protection Overlay Map Planned 78

NACE REGIONAL AND SECTIONAL NEWS

Washington University Course Schedule Completed 79
Sulfuric, Nitric Acid Corrosion Problems Discussed 79
Illinois U. Short Course 79
Northeast Region Meeting to Feature Panel 79
Permian Basin Lays Corrosion Tour Plans 80
Gasoline Plant Corrosion Is Houston Topic 80
Alamo Section Hears About Water Consultants 80
Corpus Christi Section 80
Sabine-Neches Section 80
National, Regional Meetings, Short Courses 80
NACE Calendar 80

Tank Painting Covered at New Orleans-Baton Rouge Section Meeting 81
More Data on April Cover Photograph 81
Greater Boston Section 81
Central Arizona Section 81
150 Attend Shreveport Short Course 82
Discussion Follows San Francisco Talks 82
Peabody Talks at Montreal 82
Western Region Names Smith 82
North Texas Social 82
Five Added to Editorial Review Group 84
Discussion Policy Change 84
Color Inserts Will Be Accepted 84
Tear Sheet Copies to Be Given Authors 84
Book Reviews 84

GENERAL NEWS

Formal Presentation of 1955 Whitney Award 87
Cebelcor Hears LaQue at Brussels 87
University of Melbourne Schedules Session 87
MIT Elevated Temperature Program July 11-22 87
Electrochemical Society's Corrosion Papers 87
Sulfur Dewpoint Corrosion Important 88
Unknown Factors in Boiler Water Treatment 88
Alkaline Chromate Process Details Given 90

Zinc Anodes Satisfactory in Sea Water 92
Auto Engines Cause 45 Percent of Air Load 92
Automatic Testing of Small Diameter Tubing 93
Importance of Slime in Cooling Towers 93
NACE to Use Associated Technical Service Abstracts 93
New Products 94
Personals 102

INDEX TO CORROSION ABSTRACTS 105
INDEX TO ADVERTISERS 127

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(Continued on Page 6)

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The Directory of NACE Technical Committees was published last in the May, 1955, issue of Corrosion beginning on Page 4.

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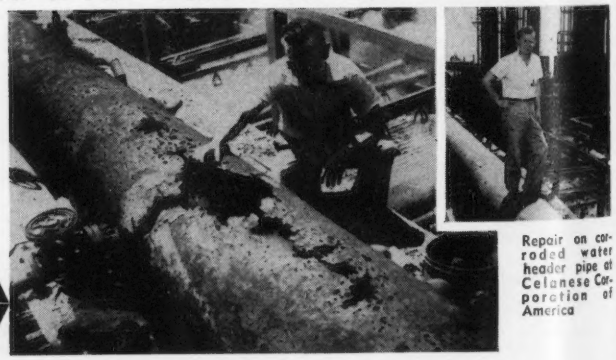

Repair on corroded water header pipe at Celanese Corporation of America

Corrosion prevention is fine . . . but AFTER corrosion . . . turn to

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RESTORES . . . REINFORCES and REPAIRS even the worst corrosion damage!

WRITE FOR price schedules on repair kits and bulk materials

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A pencil pokes through this corroded metal! Why chance trouble like this? Cathodic Protection and ANACONDA Type CP Cable effectively check corrosion of buried metals.

For longer cable life in cathodic protection —Anaconda Type CP Cable

Moisture, soil acids and alkalies, and —most important — oil are tough on present cables used in Cathodic Protection.

Anaconda's new Type CP Cable is specially designed—with double covering of polyethylene and Densheath* (PVC) — to resist these enemies of cable life. This means less frequent replacement . . . major savings in both labor and material costs.

*Reg. U. S. Pat. Off.

Polyethylene and Densheath used in ANACONDA CP Cable are inherently resistant to oil. And they have high resistance to electro-endosmosis, as well as to moisture and most acids, alkalies and chemicals found in corrosive soil areas. Rugged Densheath jacket withstands toughest abrasion, and weathering.

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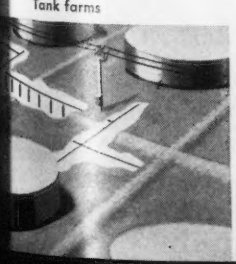
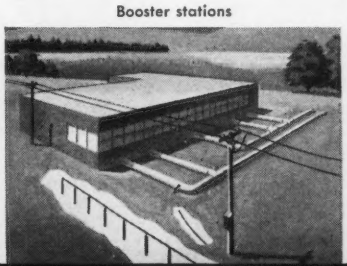
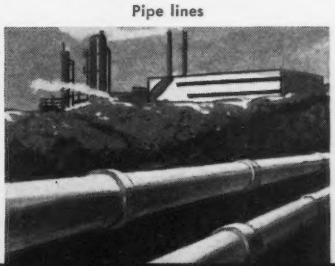
Tank farms



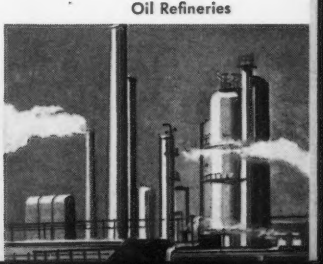
Booster stations



Pipe lines



Oil Refineries



as you read this ad...

Corrosion is taking its toll!

Protect your investment with a Harco Cathodic Protection System

Your corporate records are safely stored . . . cash is deposited under lock and key . . . the burglar alarms are wired and ready . . . and exposed property is insured. But is your protection complete?

Even as you read this advertisement, thief corrosion is stealing you blind. Every ferrous metal structure you own (buried metal pipe, water storage tanks, etc.) is being stolen from your profits. Millions of dollars are stolen annually from the unsuspecting.

Harco's job is protecting you . . . protecting your investments . . . protecting your profits. Harco job-engineered systems provide the necessary testing, drawings, materials and installation techniques. Harco installation and contracting service is completed to customers specifications, and it covers as much or as little of the total job as is required. Materials and supplies available from Harco are complete from anodes to rectifiers.

NOW is the time to stop thief corrosion! NOW is the time to specify . . .

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Write today for catalog or call MOntrose 2-2080

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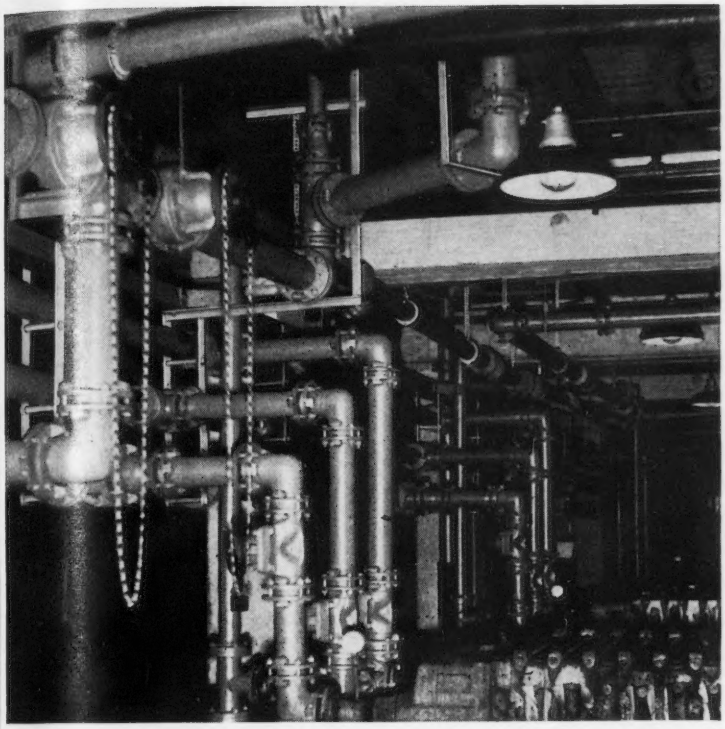
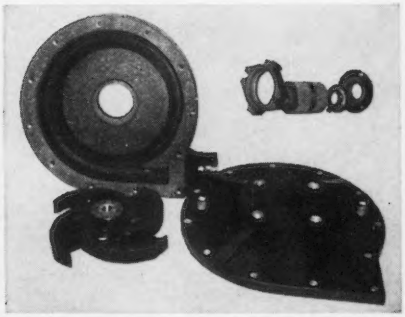
WHERE HAVEG EQUIPMENT IS INSTALLED

TRADE MARK REG. U. S. PAT. OFF.

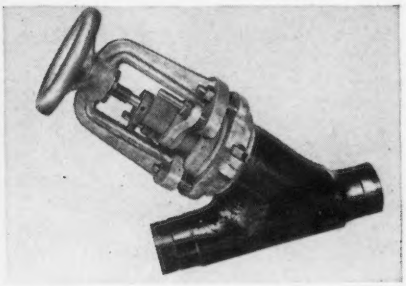
PIPE • DUCT • FITTINGS • VALVES • PUMPS



A typical large installation of Haveg pipe, valves and fittings showing simple method of support required. Haveg pipe is unaffected by thermal shock, seldom requires insulation.



These Haveg parts are used in pumps for hot (104°F.) 30% Hydrochloric acid. Typical record: 33 months without replacing a single part. Many users report even longer life.



Escape potential valve troubles by buying Haveg y-valves and diaphragm valves which are smooth-molded, exactingly machined, tested in the Haveg factory. Haveg works with you on special designs!

Processing Corrosion has been Controlled!

Where liquids get hot and corrosive, it pays to consider all the facts about Haveg piping systems. Haveg has all the major ingredients for good chemical piping. Strength. Durability. Light weight. Outstanding resistance to corrosion and thermal shock.

It withstands rapid temperature changes and enables you to go into a high range of process temperatures with complete safety and a proven history of reliable performance. Haveg piping resists corrosion of practically all acids (except oxidizing acids) and lasts for years without repairs or maintenance.

Haveg *piping* is molded in diameters of ½" up and comes in lengths to 10'. It can be cut and fitted on the job (a new Haveg tool makes this even simpler—ask your Haveg engineer for details). For handling corrosive gases or fumes, Haveg *duct* is made in cylindrical or rectangular shape with lighter walls. Fume hoods, bifurcators, fan housings, fittings, all are made from Haveg and give complete containment and control of corrosives.

It's a long story telling all about Haveg, the moldable, thermosetting plastic material made of acid-digested asbestos and synthetic resins. Haveg is both a material and a service . . . it comes from America's first molders of corrosion-resistant plastic equipment. It can be as big as a 200' stack, as small as a miniature pump part. Call the experienced sales engineer listed. Write for the 64-page illustrated Bulletin F-6 which contains size and chemical resistance charts, design specifications. Remember, Haveg is a logical, proven answer to your design problems in handling hot, corrosive liquids; in fact, in all equipment that must control processing corrosion.

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WmSON STYLE 4 THINSULATOR

The "THIN" insulator for pipe in casing

Clearance insures free movement into casing

THINSULATOR band, flexible steel lined with synthetic rubber. Band clamped with steel stud bolts.

steel runners

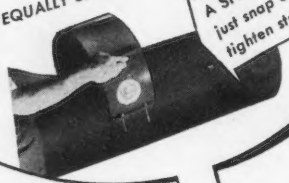
pipe line

casing

SIZES 6 x 10 to 36 x 40

THINSULATORS EQUALLY SPACED THRU CASING

A SNAP TO INSTALL just snap on pipe tighten studs . . .



WmSON CENTERING CRADLE

short massive INSULATOR centers pipe at casing end permitting easy installation of "Z" BUSHING

- carries weight of backfill dirt and insulates pipe from casing
- EASY TO INSTALL: Simply lift pipe and slip into place

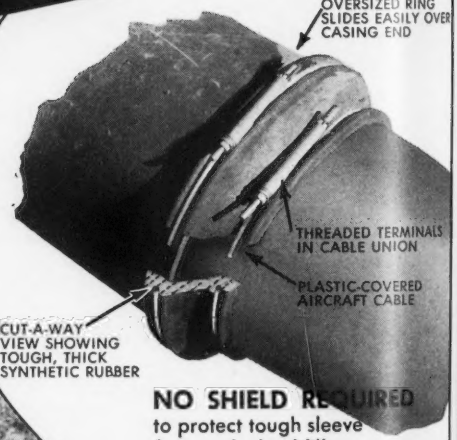
SIZES: *any combination of pipe and casing sizes.*

PIPE LINE CASING PIPE LINE

Here's why . . .

Pipe line construction specs. include WmSON BUSHINGS, INSULATORS & CRADLES for cased crossings . . .

WmSON "Z" BUSHING


OVERSIZED RING SLIDES EASILY OVER CASING END
THREADED TERMINALS IN CABLE UNION
PLASTIC-COVERED AIRCRAFT CABLE
CUT-A-WAY VIEW SHOWING TOUGH, THICK SYNTHETIC RUBBER

NO SHIELD REQUIRED to protect tough sleeve from rocky backfill

SIZES: FOR PIPE 6" AND UP IN CASING 4" OR 6" LARGER

They are "ENGINEERED" for LASTING ECONOMY . . .

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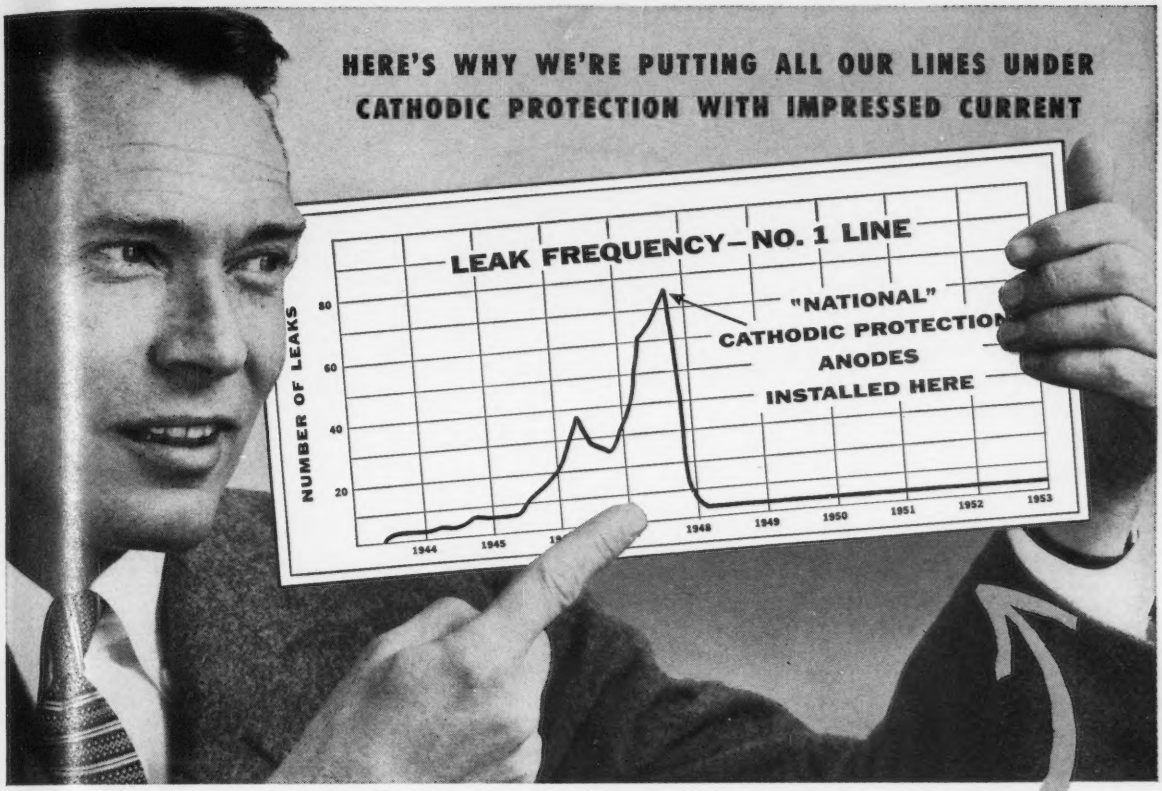

As the chart shows, one best way to virtual elimination of underground and underwater corrosion is *impressed current cathodic protection* using "National" Graphite Ground Anodes. It's the *only* kind of protection that tells you at a glance it's working — and how hard it's working — to protect your valuable investments.

HERE'S WHY YOU SHOULD USE NATIONAL GRAPHITE ANODES

TRADE-MARK

CHOICE OF MATERIAL: "National" Anodes are available from stock in two materials—*NA Graphite*, which gives maximum life under all service conditions; *standard graphite*, for dependable, long-life, underground service.

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Decide on the sure, safe, economical method of cathodic protection. Then choose "National" Anodes to do the best job at the least overall cost.

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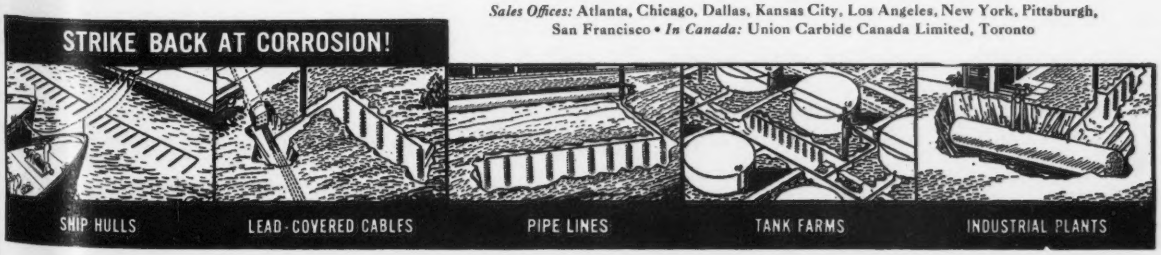

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New Improved SCOTCHRAP BRAND

First in the field...still the leader!

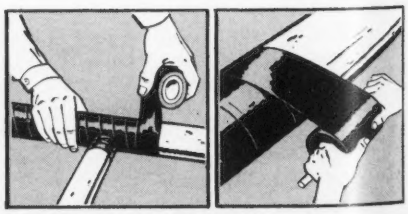
New! Super-conformability at high or low temperature. Field reports indicate satisfactory application at 0°-10°F.

New! Increased *adhesion* at cold temperatures.

New! Green corrosion-inhibitor built in the adhesive.

Plus the regular "Scotchrap" advantages! Tough vinyl plastic resists abrasion above or below ground, prevents corrosion. Pressure-sensitive adhesive sticks tight and *holds.*

FAST! "SCOTCHRAP" can be applied by hand or machine—in a hurry!



SMALL OR LARGE! "SCOTCHRAP" is sold by the square in 1", 2", 4", 6" and 8" widths. Two thicknesses: 10 mils (No. 50), and 20 mils (No. 51).

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SCOTCHRAP Pipe Insulation BRAND

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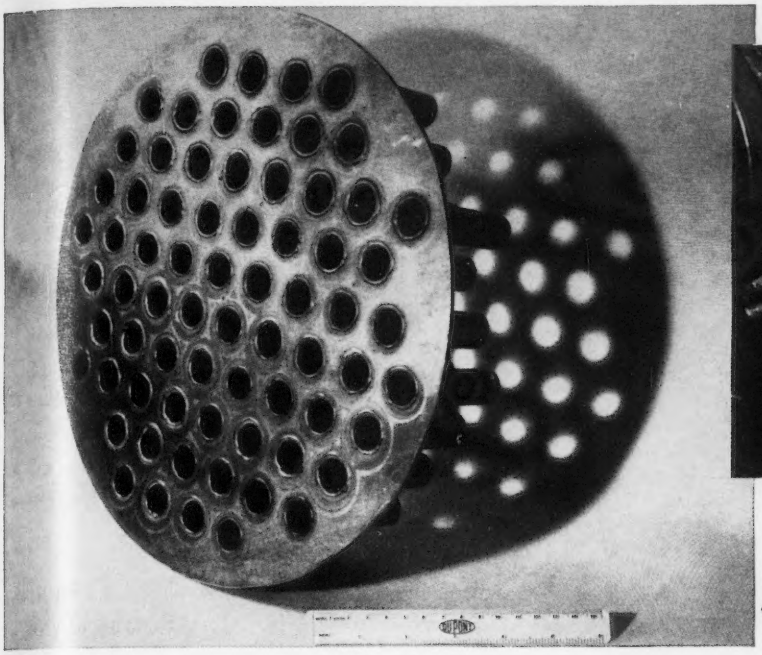

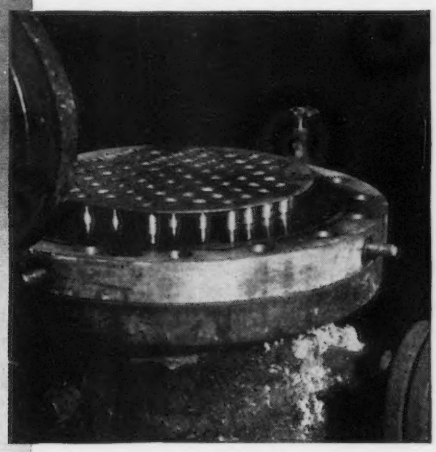

1. Titanium "top-hat" insert being placed into the condenser tube bundle. The tubes of the "top-hat" extend into the parent tubes for 3 inches. Titanium outperformed stainless steel 3 to 1.

2. Unretouched photo of titanium condenser "top-hat" insert after 14 months' service. Note clean, uncorroded appearance of tube sheet and welds.

Titanium "Top-Hat" Insert Weathers Acid Storm

No Sign of Corrosion After 14 Months' Exposure to Hot Nitric Acid

Every 4 to 6 months the entire tube assembly of a condenser at a Du Pont plant had to be replaced. Turbulent vapors of 60% nitric acid—rushing into the header at pressures of 300 psi and at temperatures of 195°C—were causing severe corrosion and erosion at the tube inlets. The top 3 or 4 inches of the stainless steel tube bundle were being literally eaten away.

The "top-hat" insert pictured above proved to be the answer to the problem. It was fabricated entirely of titanium and was designed to provide a protective sleeve inside the top 3 inches of the condenser tubes—the point at which acid attack was the most severe. After 14 months of service—of which 8 months were on a continuous 24-hour-per-day basis—the "top-hat" insert showed no sign of corrosion. The titanium tube sheet, tubes and welds of the insert had essentially the same appearance as when installed and showed evidence of being able to serve indefinitely!

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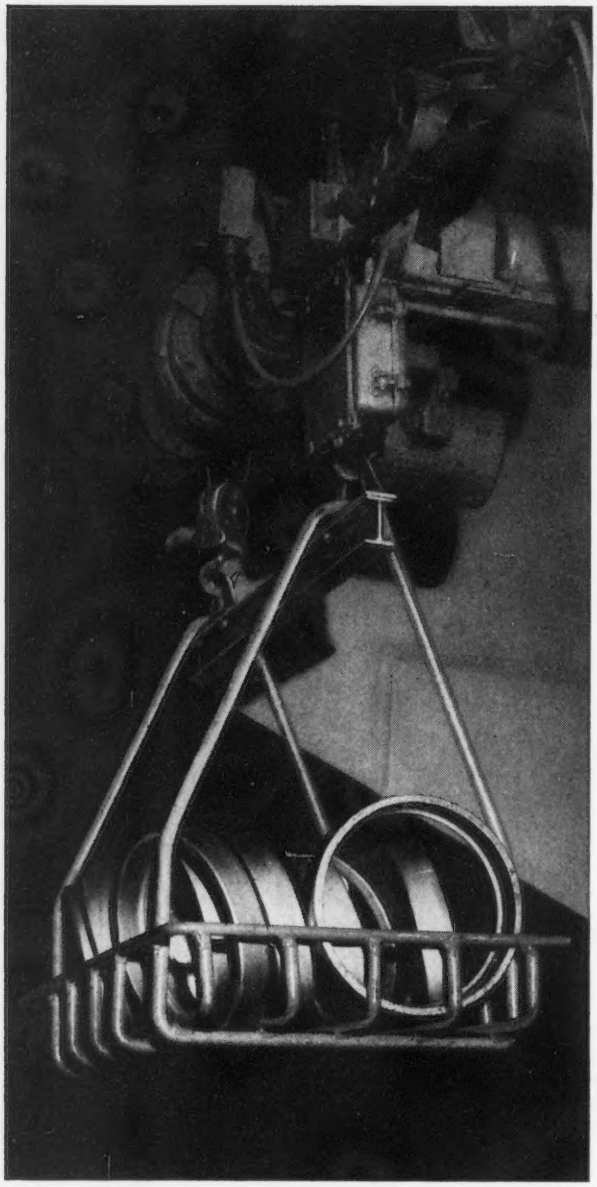

PROBLEM:

Baskets for submerging alloy steel forgings in hot pickling acids had to be replaced every month because of severe corrosion. The baskets were continually immersed in either 15 per cent hydrochloric acid, aqua regia, 10 per cent nitric and hydrofluoric acids, or 20 per cent nitric acid. All of these acids were at about 140 deg. F.

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Ucilon Coating 1901, 1951 and 458 add advantages of neoprene base materials and vinyl-Thiokol compound to available Ucilon Coatings—some of which are shown here.

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THE NATIONAL ASSOCIATION OF CORROSION ENGINEERS

is a non-profit, scientific and research association of individuals and companies concerned with corrosion or interested in it, whose objects are:

(a) To promote the prevention of corrosion, thereby curtailing economic waste and conserving natural resources.

(b) To provide forums and media through which experiences with corrosion and its prevention may be reported, discussed and published for the common good.

(c) To encourage special study and research to determine the fundamental causes of corrosion, and to develop new or improved techniques for its prevention.

(d) To correlate study and research on corrosion problems among technical associations to reduce duplication and increase efficiency.

(e) To promote standardization of terminology, techniques, equipment and design in corrosion control.

(f) To contribute to industrial and public safety by promoting the prevention of corrosion as a cause of accidents.

(g) To foster cooperation between individual operators of metallic plant and structures in the joint solution of common corrosion problems.

(h) To invite a wide diversity of membership, thereby insuring reciprocal benefits between industries and governmental groups as well as between individuals and corporations.

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Corrosion

OFFICIAL MONTHLY PUBLICATION

National Association of Corrosion Engineers

An Association of Individuals and Organizations Concerned with Control of Corrosion

1061 M & M Building Houston 2, Texas

Vol. 11 June, 1955 No. 6

Topic of the Month

Atmospheric Corrosion Of Mild Steel In a Chemical Plant*

By ROBERT I. ZIMMERER*

THE ATMOSPHERIC corrosion of steel and steel structures is common knowledge. However, the extent or rate of such corrosion is usually observed only qualitatively by evidences of rust scale, pitting and sometimes perforation. Because of the awe inspired by large quantities of rust scale and the oft asked question of the economics of paint protection a series of steel corrosion panels was exposed at several selected locations in a chemical processing plant. The corrosion data was supplementary to a maintenance paint survey and was obtained jointly with Kenneth Tator Associates. There have been several earlier presentations of similar data,[1, 2] but it was felt that the present data could add to the variety of exposures and at the same time point to the variations possible even within a single operating plant. Figure 1 shows the corrosion of mild steel at three test stations. Station 1 was outdoors and exposed to caustic, chlorine and chlorinated solvents fumes. Station 2 was outdoors adjacent to an organic chlorination unit. Station 3 was indoors in a salt plant.

The three factors[2] affecting atmospheric corrosion are: 1—The duration of wet conditions; 2—The chemical composition of the atmosphere; and 3—The composition of the corroding metal.

All the panels were sandblasted SAE 1020 steel hung vertically and the atmosphere varied according to normal production demands. Factor No. 1 was less severe than normal, there being a shortage of rain, averaging 33.7 percent below normal. While unfortunately the test series was not designed to correlate corrosion and rainfall, it has been agreed generally by those familiar with the test locations that corrosion during this period was less than normal, or in other words the reported corrosion rates can be considered minimum.

Of special interest is the rise in the cumulative corrosion rates. This upturn has been attributed to the breakdown of the rust scale after it had become too heavy to maintain its continuity. The panels which had been exposed four months or longer were found to have a scale which was readily loosened by light hammer blows. Panels of less duration exhibited a thinner scale

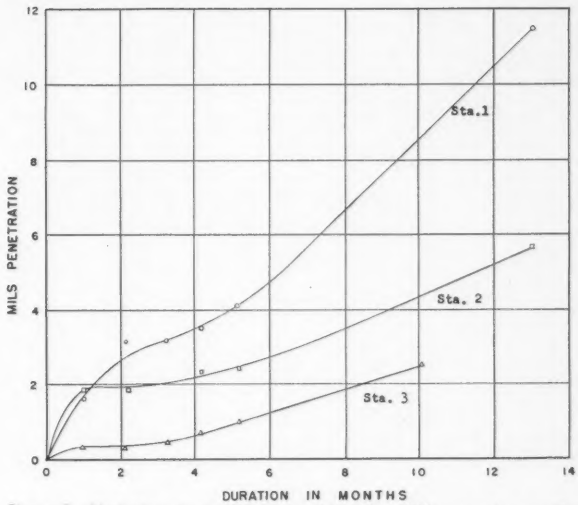

Figure 1—Variations in metal loss resulting from differences in severity of atmospheric environment.

and from this it has been inferred that the dip in the curves at 3-5 months, with increasing corrosion rates thereafter, is a valid observation. Panels exposed for about a year all exhibited irregular corrosion or pitting tendencies.

The economics of designing with additional steel as a corrosion allowance has been presented adequately by Harvey[1] and the economics of paint maintenance has been presented similarly by Pierce.[3] Assumming a medium cost of 30c/pound. for fabricated steel and an initial corrosion of 11 mils per year, a corrosion allowance of metal for 12 years' protection indicates a cost of at least 83c/square foot. Taking Pierce's cost for paint protection in a chemical plant, 12 years protection costs 87c/square foot with proper paint maintenance.

With these observations in mind several conclusions seem evident. Paint protection in chemical exposures costs about the same as extra steel in the form of corrosion allowance, but this is neglecting the inconvenience and cost of replacement outages, or the intangibles such as housekeeping, morale, safety, etc. Surface preparation costs can be expected to rise sharply after bare steel has been exposed to a chemical atmosphere for four months or longer. For a realistic evaluation of any given exposure, corrosion tests should be conducted on the site.

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★ Submitted for publication October 4, 1954.

* Maintenance Engineer, Westvaco Chlor-Alkali Division, Food Machinery and Chemical Corp., South Charleston, W. Va.

Figure 1—(Upper left) Portable rotary pump with jet nozzle dug 9-foot deep hole in one minute. (Upper right) Ground rod and water jet nozzle are started together. (Lower left) Sand flushed to surface by jet action of 1-inch diameter nozzle. (Lower right) Thirty seconds after starting water pump the anode is four feet deep.

A Technical Note

Placing Ground Contact Anodes With a High Velocity Water Jet*

By WALTER P. NOSER*

A JET of water at high velocity was used in a recent installation of high-silicon content impressed current anodes. The method of installation is equally applicable to galvanic or impressed current anodes. It is especially applicable in creek bottoms or other places inaccessible to ordinary drill trucks. A small lightweight portable gasoline powered pump could be used at such locations.

Anodes were installed by this method at the location because quicksand was found at about four feet. It would have been virtually impossible to install anodes in prepared carbonaceous backfill in holes dug by the usual rotary drill method.

A considerable sum of money was saved using this technique over the usual method because the location was relatively far removed from shipping centers for the carbonaceous material.

The illustrations indicate the ease with which the 2-inch diameter by five foot long anodes were installed to a depth of nine feet in approximately one minute. Twenty anodes were installed without backfill in two rows 20 feet apart with 20-foot spacing in each row. The soil at the location consisted of very loose sand with gravel deposits at approximately four foot depth and quicksand below the four foot depth.

★ Submitted for publication January 28, 1955.
* Humble Pipe Line Company, Houston.

After the upper four feet crust of sand and gravel had been penetrated with the water jet, the anode had a tendency to sink in the quicksand. The twenty rod ground bed replaced an existing horizontal type scrap iron ground bed which had been placed in the bottom of the adjoining creek in the quicksand. Overall circuit resistance of 1.2 ohms is approximately 0.5 ohms less for the new ground bed than for the abandoned scrap iron ground bed.

Soil resistivity measurements were made 50 feet north of the ground bed, at the center of the ground bed and 50 feet south of the ground bed and on a sand bar in the creek bottom. The measurements in ohms-centimeters are given in Table 1.

Individual leads of No. 6 TW wire were brought from four of the anodes and connected to the rectifier through 0.01 shunts. Measurements made on the four separate anodes are shown in Table 2.

TABLE 1—Resistivity—Ohm-Cm.

Pin Spacing in Feet	5 Feet	10 Feet	20 Feet
50 feet North of Ground Bed	2300	2400	3000
Center of Ground Bed	2000	2600	3500
50 feet South of Ground Bed	1400	2400	2550
Creek Bed	6600	5200	4000

TABLE 2

Anode No.	Current Drain Amperes	Anode Weight Pounds	Anode to Pipe Line Resistance Ohms	Distance From Rectifier Slab (In Feet)
4	1.62	45½	14	70 E-14 S
6	1.83	44	11	70 E-26 N
16	1.35	46	16	90 E-16 N
17	1.28	45½	14	90 E-36 N

1.3 Ohms, Resistance measured between pipe line and 16 anodes in parallel.
1.2 Ohms, Resistance measured between pipe line and 20 anodes in parallel.
4.0 Ohms, Resistance measured between pipe line and 4 anodes in parallel.

Acid Corrosion Inhibition By High Molecular Weight Nitrogen-Containing Compounds*

By RAYMOND A. GEORGE(1) and NORMAN HACKERMAN(2)

Abstract

The adsorption of various long chain amines, amine acetates, quaternary salts, and ethylene oxide-octadecylamine condensates from benzene solution onto steel was determined. The acid dissolution of steel with previously adsorbed inhibitor and the dissolution of steel in aqueous inhibited acid solution were also studied. For the dodecyl compounds of each series, 1) adsorption for a di-amine can take place through both amine groups, 2) amine salts are not as effectively adsorbed as amines and 3) a high molecular weight quaternary salt is strongly adsorbed even though it has no available bonding electrons.

Inhibitor effectiveness for these compounds adsorbed from benzene solution onto steel are in decreasing order, 1) quaternary salt, 2) di-amine, 3) mono-amine, and 4) mono-amine acetate. In inhibited acid solutions, long chain amine acetates and quaternary salts furnish better than 90 percent inhibition in the concentration range of 3.75 to 15 x 10^{-4} molar. Ethylene oxide and octadecylamine condensation products were less effective in this concentration range, providing approximately 85 percent inhibition. However, they were more effective than the amine acetates and quaternary salts where less than 3.75 x 10^{-4} molar.

Introduction

THE ELECTROCHEMICAL theory of corrosion postulates that a metal surface may acquire potentials locally and that these depend upon the reactions occurring in the vicinity. When iron is immersed in an electrolyte such as an acid, miniature, local, galvanic cells are formed with the more anodic potentials induced where the metal goes into solution. Reduction of hydrogen ion or oxygen, occurring elsewhere, induces the more cathodic potentials. Continued attack of the metal may be stopped if either reaction is stifled. Certain materials, both inorganic and organic, when added to the metal-fluid system are known to retard the rate of metal dissolution. Some of these influence the cathode reaction predominately and some exert the main effect on the anode reaction.

Evidence that organic inhibitor action is a process which involves adsorption is abundant.[1-6] Therefore, factors which relate molecular structure to adsorbability and to type of forces involved between metal and inhibitor are important. Molecular weight, solubility, type of functional group, number of functional groups, dimensions of the molecule, dipole moment, degree of association and reactivity are factors which relate to inhibitor effectiveness. Factors which relate to the metal are its reactivity and homogeneity. The lattice structure, defect, nature and porosity of its compounds which might be present, or surface films, are also important. Different solvents and other solutes such as foreign ions or other surface active agents, may be influential in altering these factors in such a way as to change the extent and type of adsorption occurring.

Some investigators in the field of acid corrosion inhibitors are of the opinion that inhibition is caused by adsorption over the cathodic areas of the surface.[4, 7, 8] Others, however, believe that organic inhibitors function at the anode regions as well. Among these is Hoar[9] who measured weight losses and corrosion potentials of mild steel in dilute H_2SO_4 with various concentrations of beta-napthoquinoline and ortho-tolylthiourea. He concluded that inhibition takes place because of general adsorption which interferes with both anodic and cathodic processes, the effect on the anodic process generally being greater. Kuznitsov and Iofa,[10] on the basis of polarization studies, also state that the inhibitor retards both hydrogen evolution at the cathode areas and solution of iron at the anode areas.

Hackerman and Sudbury[11] found the steady state potential of mild steel in 1 N H_2SO_4 and in tap water to be a function of the nature and concentration of amine additives. Studies of anodic and cathodic polarizations and decomposition potentials showed that anodic, as well as cathodic, areas were affected by added amines. The anodic effects were considered to be due to a reduction in the tendency for the iron ions to go into solution because of perturbation of bonding electrons.

Machu[12] believes that organic inhibitors give rise to a film over the entire metal surface and that this has a very high electrical resistance. The film can be considered as a barrier which simply retards diffusion to the metal.

In a more recent theory of organic inhibitor action on acid dissolution of metals, Hackerman and Makrides[13] proposed that adsorption of the inhibitor is general and that inhibitor action results from,

a) increased resistance to current flow caused by a barrier of physically adsorbed inhibitor over most of the surface, and,

b) by reduction in metal reactivity by chemi-sorbed inhibitor.

The relative contribution of the two depends upon the inhibitor. It is postulated that the binding responsible for chemisorption is the formation of a dative bond between the metal and the organic mole-

*A paper presented at a meeting of South Central Region, National Association of Corrosion Engineers, Dallas, Texas, October 12-15, 1954.

(1) Field Research Laboratories, Magnolia Petroleum Co., Dallas, Texas.

(2) University of Texas, Austin.

cule. The bond is formed through sharing a pair of electrons between the inhibitor and the metal.

In all probability inhibitive action involves all of the factors cited plus others still to be discovered. There is as yet no clear-cut proof regarding any of the rate-retarding possibilities and many factors must be considered in anodyzing the mechanism of inhibitor action.

As part of a program to obtain greater insight into inhibitive action several high molecular weight, nitrogen-containing substances were studied. Adsorption from benzene solution onto steel powder and the effect of this treatment on the reactivity of the steel in aqueous acid solution were determined. The reactivity of steel powder placed directly in inhibited acid solution also was investigated.

Experimental

Materials: The inhibitors used were amines, amine salts, quaternary ammonium salts, and ethylene oxide-amine condensates.* They were essentially pure chemical substances with regard to their functional group, i. e., the amines were essentially 100 percent amine, the amine salts were essentially 100 percent amine salts, etc. More specifically, they were of at least 90 percent purity with the existing impurities being similar molecules containing 2 or 4 methylene groups more or less than the subject compound. No further purification was attempted because this study was concerned with molecules containing different functional groups rather than with those of a given homologous series. The impurities present have no major effect upon the results obtained.

A — 140 to + 200 mesh fraction of SAE 1020 steel powder** was used in both the adsorption and metal dissolution studies. It contained 0.16 percent carbon, 0.52 percent silicon, 0.21 percent manganese and traces of sulfur and phosphorous. The specific surface area of the steel powder was 0.067 square meters per gram. This was determined by the BET method at liquid nitrogen temperatures with krypton as the sorbate.

Adsorption Measurements: Adsorption of several nitrogen-containing organic molecules onto steel powder was carried out by immersing weighed samples of steel powder into benzene solutions of the inhibitor. The amount of adsorption was determined gravimetrically by noting the weight increase of the steel powder after adsorption equilibrium was reached. Irreversible as well as total adsorption were determined. The irreversible adsorption is that portion of the material which remained upon the steel powder after repeated washings with clean benzene. The inhibitor concentrations were in the range 0.375×10^{-3} to 15×10^{-3} molar. The temperature was 30 ± 0.5 C.

A more detailed description of the adsorption and desorption procedure and the apparatus used is given elsewhere[14].

Reactivity Measurements of Steel with Previously Adsorbed Inhibitor: Five grams of steel powder with previously adsorbed material were added to 100 cc of 4 N HCl in a three-necked round-bottom flask. This was fitted with a delivery tube which led to an inverted water-filled 250 cc gas buret, partially immersed in a beaker of water. The reaction flask was immersed in a water bath and thermostated at 30 ± 0.05 C. By measuring the rate of hydrogen evolution, the rate of acid attack upon the steel was determined.

The inhibitive effectiveness of the compound adsorbed on the steel is given by

$$\% \text{ of inhibition} = \frac{\text{rate of dissolution of clean steel} - \text{rate of dissolution of steel with inhibitor}}{\text{rate of dissolution of clean steel}} \times 100$$

The percent inhibitions for 0-1.6, 1.6-3.2 and 3.2-4.8 percent dissolution of steel were determined, i.e., for time for given volume of hydrogen to be produced. Only the data for the first fraction are tabulated here because the other values are not especially pertinent to this study.

Reactivity Measurements of Steel in Acid Inhibitor Solutions: Other inhibitor studies were made in which the acid was added to an aqueous inhibitor solution or dispersion. For this test, five grams of clean steel powder (— 140 to + 200 mesh), washed with benzene, was added to 25 cc of the solution or dispersion in a three-necked, round-bottom flask. The flask was fitted with a delivery tube which led to an inverted, 250 cc water-filled gas buret partially immersed in a water bath at 30 C. One minute following addition of the steel powder, 75 cc of 5 N HCl was added to the system. The acid concentration in the flask ended up at 3.75 N. Hydrogen was evolved and collected over the interval equivalent to 0—2 percent dissolution of the steel powder. The percent inhibition was calculated and compared with the inhibitor solution concentration. Inhibitor concentrations reported are the final values resulting after addition of acid. They were chosen in the range 0.47×10^{-4} to 15×10^{-4} molar for all materials studied except octadecylamine-ethylene oxide condensates. The range was extended down to 3×10^{-6} molar for these inhibitors because greater inhibition was observed at the lower concentrations.

Results and Discussions

Adsorption from Benzene Solution: Adsorption isotherms were obtained for six different compounds. These results given in Table 1 and Figures 1-2, show that varying amounts of total adsorption and irreversible adsorption occur depending upon the properties of the molecule in question.

Dodecylamine showed considerable total and irreversible adsorption while its salt, dodecylammonium acetate, reacted with the steel powder. The reaction products come off the surface; this to such an extent at higher inhibitor concentrations that an apparent negative adsorption was measured. The reaction between steel and the amine acetate was probable preceeded by hydrolysis of the salt at the steel surface, followed by acetic acid attack upon the steel. The

* All kindly furnished by the Chemical Division of Armour and Company, Chicago.
** Obtained from Vanadium-Alloys Steel Company, Latrobe, Pa.

solubility of water in benzene is sufficient to account for the hydrolytic action.

Irreversible adsorption of dodecyl, 3-amino propylamine and of alkyl (tallow), 3-amino propylamine were noticeably small. This suggests that the diamine was adsorbed through both nitrogen-containing groups and therefore lies flat on the surface. This is based on the assumption that both amines, regardless of their specific reactivity were eventually adsorbed in a monolayer over the same area of the metal surface. It is substantiated by previous studies which showed that the amount of long chain, aliphatic, primary amine irreversibly adsorbed from benzene onto steel powder was nearly constant for the homologous series[14], and from calculations made on the surface coverage obtained. The irreversible adsorption of dodecylamine in this adsorption experiment covered about 30 percent of the total surface area. In these calculations, the area used was that determined by the BET method and 20.5 A^2 was used as the area occupied by a vertically oriented amine molecule.

The adsorption of the dioleate salt of alkyl (tallow), 3 amino propylamine was essentially all reversible with only a trace of irreversible adsorption. The possibility of such a molecule being irreversibly adsorbed is slight because of the loss of two of its more reactive bonding electrons in salt formation. The ability of such a large complex molecule to orient itself so that adsorption can take place through both nitrogen atoms before excessive physical adsorption takes place could be a determining factor.

Irreversible adsorption also was obtained with didodecyl-dimethyl-ammonium chloride, indicating that the forces holding these attached molecules are strong. The exact nature of these forces is not known, but it is unlikely that any covalent bond formation could occur. They are in all probability held physically rather than chemically. Under some conditions electrostatically bound material might be strongly held. For example, the force between charged particles depends on the distance between the charges themselves, and inversely, on the dielectric constant, D, of the medium. For water at normal temperatures, D is 80, so electrostatic forces would be small. In an oriented film it is conceivable that D might be very small and, if so, the bonding force would be larger. For example, if the bond energy is 1 kcal per mole for D = 80, it would be 40 kcal per mole for D = 2. This compares favorably with chemical bond strength.

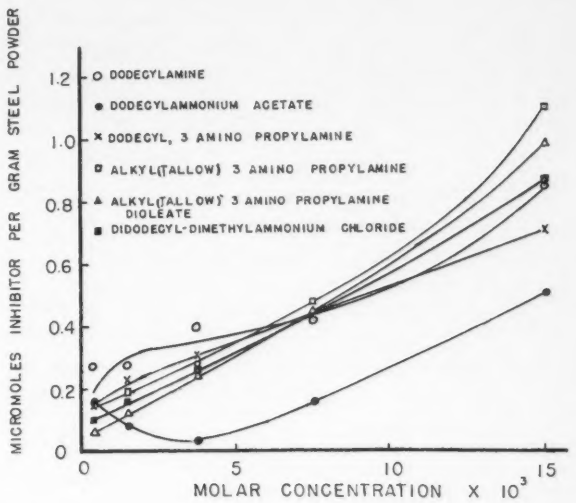

Figure 1—Adsorption of inhibitor from benzene onto steel (total).

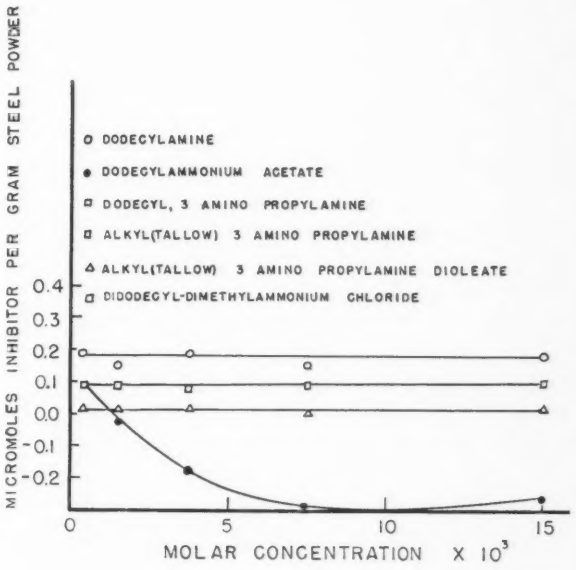

Figure 2—Adsorption of inhibitor from benzene onto steel (irreversible).

Protective Action by the Previously Adsorbed Inhibitor: The firmly attached material (irreversible adsorption) was found to furnish a large portion of the protective action for the materials studied (Table 2 and Figures 3-4). However, when sufficient reversible adsorption occurred, greater inhibition resulted. This was probably due to the larger amount of multi-layered inhibitor available for replacement of the adsorbed molecule once acid attack commenced. Of course, the physi-

TABLE 1—Adsorption of Inhibitor From Benzine Solution Onto Steel (moles/g. steel)

Inhibitor	ADSORPTION CONCENTRATION, MILLIMOLAR									
	0.375		1.50		3.75		7.50		15.0	
	Total	Irrev.	Total	Irrev.	Total	Irrev.	Total	Irrev.	Total	Irrev.
Dodecylamine	0.27	0.19	0.27	0.15	0.40	0.19	0.42	0.15	0.85	0.08
Dodecylammonium acetate	0.16	0.10	0.08	−0.02	0.03	−0.17	0.16	−0.29	0.51	−0.26
Dodecyl, 3 amino propylamine	0.15	0.07	0.23	0.07	0.31	0.07	0.43	0.05	0.71	0.10
Alkyl (Tallow), 3 amino propylamine	0.14	0.12	0.19	0.10	0.28	0.08	0.58	0.09	1.10	0.10
Alkyl (Tallow), 3 amino propylamine dioleate	0.06	0.02	0.12	0.02	0.24	0.02	0.45	0.00	0.98	0.02
Didodecyl-dimethylammonium chloride	0.10	0.08	0.16	0.08	0.26	0.08	0.42	0.09	0.87	0.10

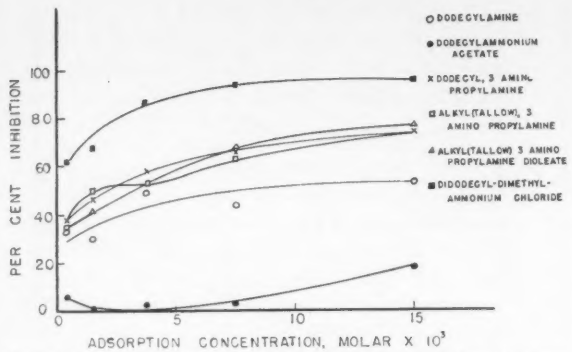

Figure 3—Protective action of inhibitor adsorbed (total) from benzene onto steel in acid.

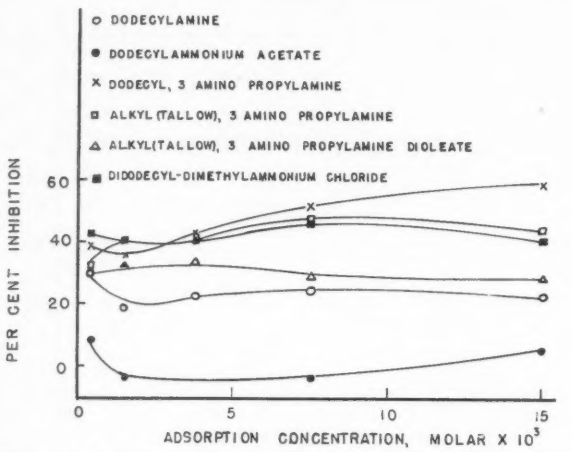

Figure 4—Protective action of inhibitor irreversibly adsorbed from benzene onto steel in acid.

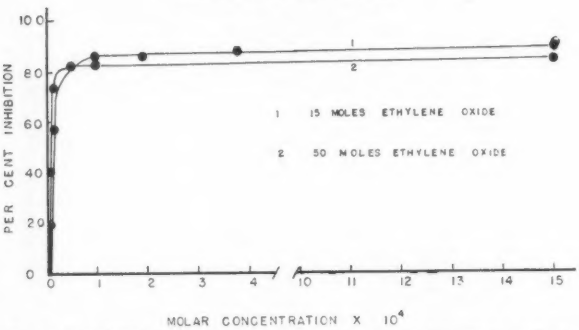

Figure 5—Inhibition of acid attack on steel by condensation products of octadecylamine and ethylene oxide.

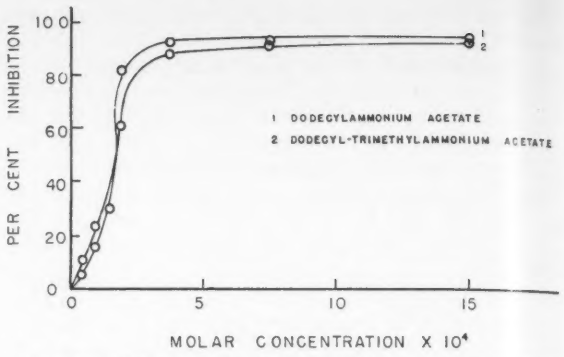

Figure 6—Inhibition of acid attack on steel by mono-amine acetates.

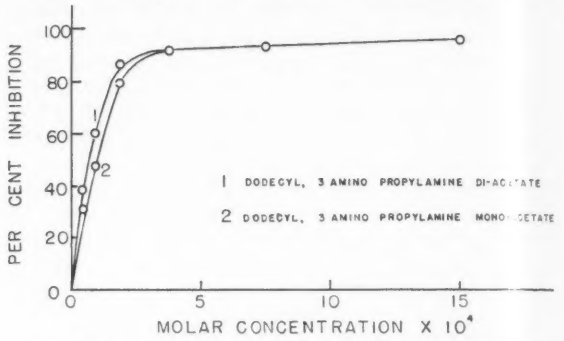
1 DODECYL, 3 AMINO PROPYLAMINE DI-ACETATE
2 DODECYL, 3 AMINO PROPYLAMINE MONO-ACETATE
PER CENT INHIBITION
MOLAR CONCENTRATION X 10⁴

Figure 7—Inhibition of acid attack on steel by di-amine acetates.

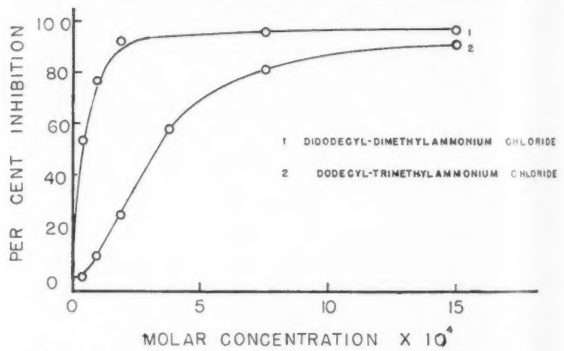

Figure 8—Inhibition of acid attack on steel by quaternary salts.

cally held film is certainly effective also in separating the corrosive medium from the steel surface.

The two di-amines were both more effective in inhibiting acid attack on steel than was the mono-amine even though fewer molecules of these inhibitors were absorbed. This suggests that firmness of adsorption or the extent of surface coverage were important. The surface coverage by the di-amine molecule when adsorbed through both nitrogen atoms was considerably greater than the space occupied by the long chain mono-amine. This is so because five atoms of the molecule, including the two nitrogen atoms had to lie along the surface if adsorption occurred in this way. A molecule which is adsorbed through two reactive groups is less likely to be removed from the metal than if it had only one such reactive group. If one of the reactive groups were separated from the metal by the corrosive agents or products, the other could still hold the molecule to the surface. Furthermore, if the molecule were so anchored to the surface, the unattached group could have been readily re-adsorbed since it was already near the surface.

Reactivity of Steel in Inhibited Acid Solution: The effectiveness observed for several different inhibitors was to a large extent dependent upon the inhibitor concentration (Table 3 and Figures 5-8). Inhibitive action at the higher concentrations and its decrease resulting from decrease in inhibitor concentration differed markedly for several of the materials studied.

The condensation product of ethylene oxide and octadecylamine had nearly constant relative activities in the concentration range of 1×10^{-4} to 1.5×10^{-3} molar. At higher inhibitor concentrations, slightly

TABLE 2

Protective Action of Inhibitor Adsorbed From Benzene Solution Onto Steel in 4 N HCl Solution (Percent Inhibition)

Inhibitor	ADSORPTION CONCENTRATION, MILLIMOLAR									
	0.375		1.50		3.75		7.50		15.0	
	Total	Irrev.	Total	Irrev.	Total	Irrev.	Total	Irrev.	Total	Irrev.
Dodecylamine	33.0	30.0	30.0	19.0	49.0	23.0	44.0	25.0	53.0	23.0
Dodecylammonium acetate	6.0	9.0	0.0	−3.0	3.0	0.0	3.0	−3.0	18.0	6.0
Dodecyl, 3 amino propylamine	38.0	39.0	47.0	36.0	58.0	43.0	66.0	52.0	74.0	59.0
Alkyl (Tallow), 3 amino propylamine	35.0	33.0	50.0	41.0	53.0	41.0	63.0	48.0	74.0	45.0
Alkyl (Tallow), 3 amino propylamine dioleate	37.0	29.0	42.0	33.0	52.0	33.0	68.0	29.0	77.0	29.0
Didodecyl-dimethyl ammonium chloride	62.0	43.0	68.0	42.0	87.0	41.0	94.0	46.0	96.0	41.0

TABLE 3

Inhibition of Acid Attack on Steel by Various Nitrogen-Containing Organic Molecules in Inhibited 3.75 N HCl Solution

(Percent Inhibition)

Inhibitor	INHIBITOR CONCENTRATION, MOLAR x 10^4							
	15.0	7.5	3.75	1.88	0.94	0.47	0.02	0.03
Dodecylammonium acetate	94.5	93.4	92.5	82.2	16.0	6.0	....	....
Dodecyl trimethylammonium acetate	92.8	92.0	88.2	61.0	24.0	11.0	....	....
Dodecyl, 3 amino propylamine mono-acetate	95.2	94.1	92.4	79.8	47.7	31.3	....	....
Dodecyl, 3 amino propylamine di-acetate	96.3	94.6	92.8	87.5	60.4	38.8	....	....
Dodecyl trimethyl-ammonium chloride	91.5	81.9	58.0	25.0	9.0	0.0	....	....
Didodecyl-dimethyl-ammonium chloride	97.4	96.4	....	92.7	77.0	53.7	....	....
Octadecylamine-ethylene oxide (15 mols)	88.4	88.2	87.3	85.2	85.7	81.8	56.8	19.6
Octadecylamine-ethylene oxide (50 mols)	83.6	84.4	....	....	82.8	80.8	73.0	40.8

less inhibition was observed for the larger condensation product than for the smaller. However, at more dilute concentrations, the larger molecule became more effective as an inhibitor.

It appears that a controlling factor in the inhibitive action of such molecules might be the freedom of movement of the inhibitor molecule in the solution and at the surface of the metal. This is determined by the concentration, the size of the molecule and the degree of association. Increased freedom of movement, thus fewer entanglements, could bring about more and better oriented adsorption for the smaller molecules. Decrease in size of the molecule or in concentration should cause no decrease in inhibitor effectiveness if more than enough inhibitor is present to be adsorbed over the whole accessible surface areas and to provide for rapid replacement for those inhibitor molecules which become separated from the steel surface. Thus, there is a lower limit of concentrations at which a decrease in inhibitor effectiveness should occur.

Inhibitor studies with various condensation products of a rosin amine and ethylene oxide showed that the product of five moles of ethylene oxide and the amine was the most effective inhibitor of the group.[15] Thus, it appears that with a decrease in the number of ethylene oxide units on the octadecylamine, better inhibition than that obtained from the material used in this work would result. This may simply be a question of decreased solubility.

Results obtained for dodecylammonium acetate and dodecyl-tri-methylammonium acetate indicate some factor other than surface coverage was involved as the primary amine acetate was a better inhibitor than the tertiary amine acetate. Increased forces of adsorption, freedom of movement, rate of adsorption and rate of orientation at the surface would favor the smaller molecule.

The di-acetate salt of dodecyl, 3-amino propylamine was slightly more effective than the mono-acetate salt at lower concentrations. This could be ascribed to the greater reactivity of the di-acetate salt brought on by its greater cationic strength in aqueous inhibitor solution. This is contrary to other deductions drawn here however.

The replacement of one of the methyl groups of dodecyl-trimethyl-ammonium chloride by an additional dodecyl group markedly increased inhibition. Either steric effects or limited solubility of the larger quarternary compound were undoubtedly the controlling factors involved. In this case it is unlikely that the change in alkyl group would change the reactivity of the nitrogen atom sufficiently to account for the large difference in inhibitor effectiveness. Kinetic effects were ruled out as controlling factors because fewer entanglements, faster adsorption and more rapid orientation would be expected to occur with the smaller molecule.

Conclusions

The inhibitor action of high molecular weight organic compounds studied is attributed primarily to the establishment of a diffusion barrier which separates the corrosive medium from the metal surface. The barrier is established by adsorption of the inhibitor generally over the surface. The protective action of such a barrier is dependent upon those properties of the inhibitor molecule which increase 1) barrier depth, 2) closeness of packing of adsorbed molecules, and 3) forces between adsorbed inhibitor and metal. Thus solubility, tendency toward aggregation, number of bonding sites and nature of bonding sites for the inhibitor molecule are all of importance.

Acknowledgment

This work was supported by a grant from Armour and Company, Chemical Division, and the authors are happy to express their gratitude to them for their aid.

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DISCUSSION

Questions by A. H. Roebuck, Continental Oil Co., Ponca City, Okla.:

1. To what do you attribute the effectiveness of the dioleate in reducing relative activity in view of the small adsorption values indicated?

2. Do you consider what you term a "diffusion barrier" the same thing as a molecular film? Approximately how thick do you consider this layer to be for an average molecular weight inhibitor?

Reply by Norman Hackerman:

1. The effectiveness of alkyl (tallow) 3, amino propyl amine dioleate was probably due to its ability to adsorb through two reactive groups. Such adsorption would provide more surface coverage per adsorbed molecule. The adsorbed molecule also would present a substantial barrier because of three long alkyl chains orientated away from the surface.

2. A diffusion barrier is considered to be anything that separates the corrosive medium from the metallic surface. This can range from a monomolecular adsorbed film to heavy scale with its thickness varying from one molecular dimension to the thickness of the scale. The thickness of such a barrier formed by an average molecular weight inhibitor is probably on the order of two hundred Angstroms. Some materials can inhibit in films only twenty-five Angstroms thick, although these certainly do not inhibit by barrier action only.

Any discussions of this article not published above will appear in the December, 1955 issue.

A Technical Note

An Automatic Circuit Interrupter For Use in Cathodic Protection System Design★

*By L. SCHWALM**

IN THE design of a cathodic protection system it is necessary to predetermine the amount of current needed to protect the structure under consideration. This is usually arrived at by forced drainage of the structure, with a battery or generator, to a temporary ground bed and measuring the amount of current needed to satisfy whatever criteria are used to determine protection. It is desirous to interrupt this drain current at known periods in order to determine the change in structure potential as well as changes in neighboring structures.

Manual circuit interruption is tedious, inaccurate and requires manpower. A dependable automatic interrupter can be built by using the relaxation oscillator circuit shown in the sketch. Two tubes are used with resistance coupling, the output of one tube being fed to the input circuit of the other. The oscillation frequency is controlled by the reciprocating change of current through the charging and discharging of the condensers and is determined by the resistance-capacity combination. Operation of the plate circuit relay RY_1, actuates the mercury drain relay RY_2. The closed and open period of RY_2 is controlled by adjustment of R_3 and R_4 respectively. Although the time intervals can be varied from .25 second to 18 seconds, it has been found that 5 seconds closed and 15 seconds open allows sufficient time to read a meter and also to differentiate between closed and open periods.

The entire unit can be contained in a case 7 x 7 x 11 inches, including the batteries. Standard radio size dry batteries will last approximately 80 hours under sustained test. Exclusive of the mercury relay, the unit can be constructed for less than $10.

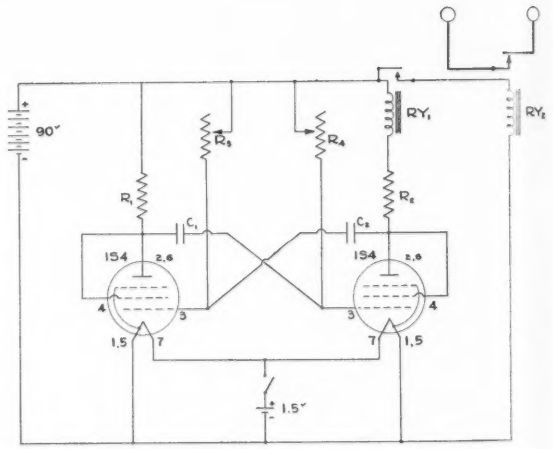

Figure 1—Circuit interrupter.
R_1 = 12,850^W ± 10% ½ watt.
R_2 = 12,850^W minus RY_1 Coil Res.
R_3 and R_4 = 2 meg. pot.
C_1 and C_2 = 30 mf — 150^V electrolytic.
RY_1 = Must have coil res. of 12,850^W or less. Must be able to operate on 5 MA. (Potter and Brumfield—Type LS-5-10,000^W Coil)
RY_2 = Must be able to break external circuit load—115 Vac—30^A and 48 Vdc—30^A (E. Bert Electronics—Type EM-1).
Note: Adjust R_3 for length of closed circuit period (from 0.25 sec to 18 seconds approx.) Adjust R_4 for length of open circuit period (from 0.25 seconds to 18 seconds approx.)

★ Submitted for publication December 22, 1954.
* 820 Superior N.W., Cleveland, Ohio.

Use of the Pearson Bridge In Corrosion Inhibitor Evaluation*

By E. J. SIMMONS

EVER SINCE oil and gas producing companies became aware of the fact that corrosion of equipment accounted for a substantial portion of their operating expense there has been a general increase in the technical effort to reduce this expense. During World War II this technical effort received its greatest impetus due to the need for conserving scarce materials. The lessons learned during these critical shortages proved that operating expense could be lowered and now it is generally agreed, even though the problem of critical materials is no longer acute, that it is economically sound to direct more and more effort towards lowering corrosion costs.

All are familiar with the various methods of preventing corrosion. It is almost axiomatic that, given a corrosion problem one or more of the following approaches is employed:

1. Use of materials which do not corrode.
2. Separation of the corrosive environment from the corroding material by means of an impervious coating of some kind.
3. Application of a protective current to the surface of the corroding material.
4. Use of chemicals in the environment which act in various ways to protect the corroding materials.

Without detracting from the importance of the first three approaches, it may be said that for reducing internal corrosion in oil and gas wells the use of chemicals generally has proved to be more effective and economical than any other method.

There are several hundred chemical compositions available today which are effective to a certain extent in combating corrosion. The selection of chemicals as corrosion inhibitors has been quite a challenge to corrosion technologists, to the extent that much time and effort has been expended in developing methods to measure the efficiency of these materials as an aid in their choice for actual field applications.

Two Test Methods Used

Most of this effort has gone towards the development of laboratory test methods which would give some indication of the quantitative or relative efficiency of an inhibitor in reducing corrosion. These methods may be divided into two general classes:

1. Direct methods which utilize a measurement of some material consumed or produced during the corrosion reaction and the effects of chemical additives on this reaction.
2. Indirect methods which measure some action of the chemical additive, such as its adsorption-desorption rate or its film resistivity, or which measures the corrosion reaction rate by measurement of the local action current.

★A paper presented at a meeting of South Central Region, National Association of Corrosion Engineers, Dallas, Texas, October 13-15, 1954 and at the Tenth Annual Conference, National Association of Corrosion Engineers, Chicago, March 7-11, 1955.

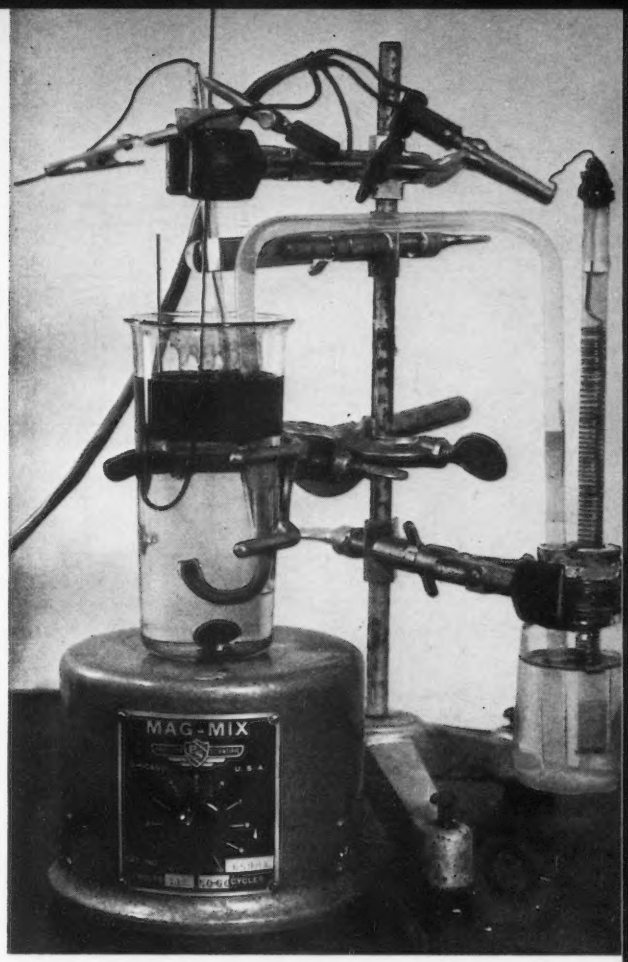

Figure 5—Close up view of cell used to obtain E vs I and ($\triangle E/\triangle I$) vs time curves.

E. J. SIMMONS—Supervisor of the chemical test section of the Production and Research Laboratory, Sun Oil Company, Dallas. The section includes groups working on corrosion service and research, analytical testing and special problems research. He attended Southern Methodist University, majoring in chemistry and biology and has been with Sun since 1940.

Abstract

The basic operation of the Pearson bridge, a circuit for measurement of electrode potentials of remote electrodes in the presence of current flow, is described. Data on the effect of impressed current on the potential of steel electrodes in various systems containing corrosion inhibitors are presented. Certain oil-soluble inhibitors appear to form a film on the metal surface which causes a high rate of change of electrode potential with change in impressed current. The semi-quantitative relationship of this change, called for simplicity a film resistance, is demonstrated. Adsorption and desorption rates can be determined from this relationship. Inhibitors which adsorb rapidly invariably give nearly 100 percent protection in weight loss tests, whereas inhibitors which adsorb more slowly show a percent protection which is dependent on the relationship between adsorption time and duration of test. Water-soluble organic inhibitors do not exhibit this type of film, which may actually be dependent on the oil phase itself for its formation.

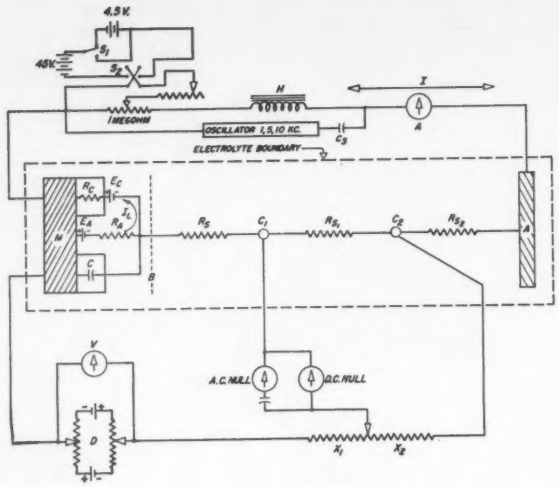

Figure 1—Block diagram of Pearson Bridge circuit. (See text for explanation.)

Most laboratories, including the author's own, have experimented at length with such direct methods as weight loss of metal coupons, hydrogen evolution, iron count and most continue to use some variation of these methods in choosing inhibitors for field use. Most of these methods have been adequately described in the literature.

This article will describe various indirect approaches to the problem of corrosion inhibitor evaluation utilizing a circuit which has come to be known as the "Pearson Bridge." This circuit was first described in the *Transactions of the Electrochemical Society* in June, 1942[1] by the late Dr. J. M. Pearson. About 1950, when the problem of inhibitor evaluation first began to make its presence known, it was suggested that this instrument might be used to study the effects of inhibitors.

In Pearson's original paper descriptions of the method used to measure local action current were given. This appeared to be a logical approach to the problem, because if local action current could be measured in a corroding system, when an inhibitor was added the degree of current suppression would naturally be a direct measurement of the inhibitor efficiency. Initial tests on such inhibitors as sodium chromate, sodium nitrite and other inorganic materials demonstrated this suppression of local action current.

Simple Approach Inapplicable

In pursuing this work into the field of organic inhibitors, however, this simple approach was not applicable. It soon became apparent that in studying oil-soluble inhibitors, oil was necessary to transport the inhibitor to the metal surface. In trying out several physical combinations, a phenomenon was noted which became the basis for later development.

In applying an external current to a metal electrode corroding in an electrolytic medium, it is found that fairly high current densities are necessary before any significant shift in electrode potential is observed. If the metal electrode has been exposed first to a layer of crude oil in which certain polar organic inhibitors are dissolved, it takes only a minute current to cause a relatively large shift in electrode potential. This is thought to be due to the presence of an adsorbed layer of inhibitor molecules. With this relationship, not only can the adsorption-desorption time be determined, but some characteristic of the adsorbed film closely akin to resistivity can be determined.

Correlation is obtainable between adsorption time and percentage of protection and in general those inhibitors showing the highest film resistivity give the greatest percentage of protection in laboratory weight loss tests. While the implication that these tests will supplant other types of laboratory tests is not intended, it is believed that a useful tool has been developed which can be utilized, at present in a limited sense, to augment information obtainable from other sources and to furnish some insight into the mechanics of inhibition.

Pearson's original paper gave a thorough analysis of the bridge circuit, and Cross and Hackerman[2] have included a brief summary of the technique. Since it has been found for the work on adsorbed films that certain portions of the circuit are unnecessary, only a brief resume of the complete operation will be given here.

Circuitry Explained

Figure 1 shows a very simplified block diagram of the Pearson Bridge connected to its electrodes in a corrosive medium (outlined by dotted lines). M represents a corroding metal electrode with its anode and cathode areas lumped diagrammatically into one cathodic area, represented by cathodic resistance R_c and cathode potential E_c, and one anodic area, represented by anodic resistance R_a and anode potential E_a. The capacitance symbol, C, is shown as shunting R_c and R_a, since the usual boundary between an electrode and its surrounding solution behaves as though it had a large electrical capacitance. Actually it is only because the electrode potential requires time to come to equilibrium after a change in current, i.e., ΔE lags behind ΔI, that a high capacity per unit area is ascribed to it. This has a practical significance which will be explained later.

Local action or corrosion current (I_L) on the face of the electrode would be equal to $(E_c - E_a)/(R_c + R_a)$. R_s represents the electrolytic solution resistance between the electrode boundary, B, and the first reference half cell, C_1 (a copper-saturated copper sulfate half cell); Rs_1 the solution resistance between the two reference half cells C_1 and C_2, and Rs_2 the solution resistance between C_2 and A, a noble metal electrode (platinum or gold) used solely to complete the impressed current circuit.

The top half of the diagram represents the DC and AC supply and measurement circuit, isolated from each other by a high capacitance and inductance, C_3 and H. By a switching arrangement S_1, it is possible to vary the EMF, and consequently the impressed current, by 10 percent, by cutting in or out of the circuit a battery whose EMF is 10 percent of the main current supply battery. The switch S_2 provides a means for reversing the direction of current flow. The AC supply consists of an oscillator with output frequencies of one, five and ten kilocycles per second. The meter, A, is a 25-0-25 microammeter whose scale, by various switching arrangements (not shown in the diagram) can be multiplied by 10, 100, 1000 or 10,000 and with a recent modification not published in the original paper, times 0.1.

This gives a measurable current range of from 0.1 μ A to 250,000 μ A (250 mils.)

The bottom half of the diagram is the potential measurement circuit, consisting of a one megohm potentiometer $X_1 - X_2$, a DC null indicator (a high impedance DC amplifier and calibrated voltmeter), and an AC null indicator consisting of an amplifier which responds to AC and excludes DC, connected to an AC voltmeter. The battery-potentiometer combination, D, provides a back EMF opposing the electrode potential. When this backing out potential is equal to that of the electrode (as determined by the DC null meter), the voltmeter, V, indicates the potential drop across the electrode boundary, including any IR drop in the electrode film and R_s due to any external current which may be flowing.

When the DC supply circuit is closed, there usually will be a deflection noted on the microammeter due to the slight EMF between M and the platinum electrode A. This is backed out by an opposing EMF in the current supply circuit until the microammeter reads zero. The calibrated meter in the DC null circuit is brought to zero by the battery-potentiometer combination D, and V then is equal to the potential difference across the electrode boundary. Since no current is flowing, there is no IR drop across the boundary.

When current is applied, however, an IR drop occurs at all resistances in the circuit. By taking advantage of the shunting effect of capacitance C to alternating current, an AC potential difference is applied to balance bridge $X_1 - X_2$ until the AC null indicator reads a minimum. At this time the AC potential difference between C_1 and the center tap of $X_1 - X_2$ is zero, showing that the following relationship exists:

$$\frac{R_s}{X_1} = \frac{R_{S_1}}{X_2}$$

since the shunted resistances R_a and R_c which are equivalent to $(R_aR_c)/(R_a + R_c)$, (a value which could logically be called the film resistance) have been bypassed by the capacitance C.

Any direct current now applied to the electrode M produces an IR drop which would be algebraically added to the electrode potential. With direct current flowing, it is possible to vary the applied EMF by 10 percent by closing S_1. Bridge $X_1 - X_2$ is readjusted so that a minimum deflection occurs when S_1 is opened and closed. This removes from the electrode potential the effects of IR drop in the film and gives the true electrode potential. The difference between this value and that obtained with the AC null is the IR drop, and, since I is known, R can be calculated. Current can be stepped up in increments depending on the type of system being studied, resulting in a set of curves similar to those in Figure 2, which represents a plot of electrode potential vs applied current. The system is a steel electrode in aerated salt water. The dash line gives the measured electrode potential using the AC null to correct for IR drop in the solution, and the solid line shows the true electrode potential after rebalancing the bridge with incremental variations in impressed current. The dotted line shows

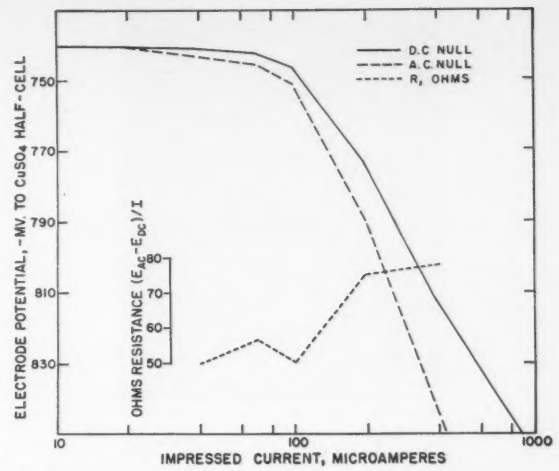

Figure 2—Cathodic polarization curves of steel in salt water, showing values obtained with AC null and DC null. Resistance is calculated from the relationship: $R = (E_{AC} - E_{DC}) / I$.

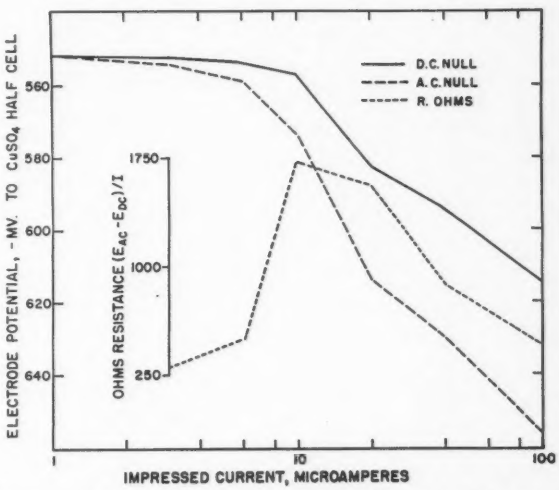

Figure 3—Same system as in Figure 2 with 1000 ppm Na_2CrO_4 added.

the calculated value of film resistance, from the relationship:

$$\frac{R_aR_c}{R_a + R_c} = \frac{E_{AC} - E_{DC}}{I}$$

Figure 3 shows data for the same system with the addition of 1000 ppm sodium chromate.

Three distinct differences are noted in these two sets of data:

First—The electrode potential at no current (which is actually not shown on the semi-logarithmic graph paper, but is the same as that for the first current value shown) is about 210 MV more cathodic (i.e., less negative) in the system containing chromate. It is generally assumed that sodium chromate is an anodic inhibitor and if R_a is imagined to be increased greatly by the adsorption of chromate ions or by the deposition of iron chromate, as is generally supposed, the electrode potential would be expected to become

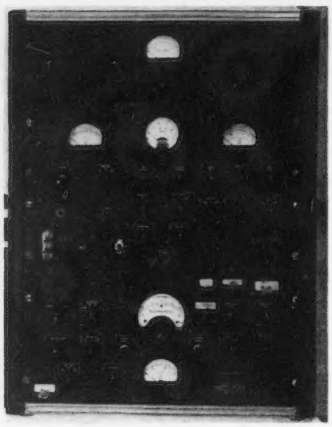

Figure 4—Front view of Pearson Bridge.

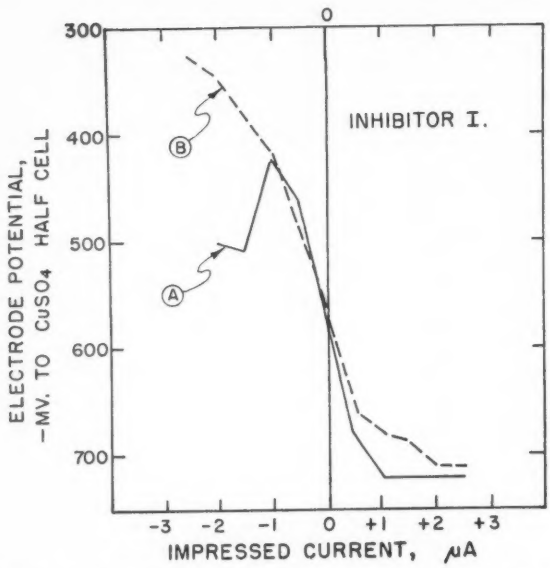

Figure 6—Electrode potential vs impressed current curves for steel in sour crude-salt water. Crude oil contains Inhibitor I. Curve A shows results with 2-hour contact; Curve B, 20-hour contact.

more cathodic since the following relationship exists:

$$E = E_a \frac{R_c}{R_a + R_c} + E_c \frac{R_a}{R_a + R_c}$$

(from Muller's accepted hypothesis of the elements entering into the electrode potential).[3]

Second—Following Pearson's proof that the value of impressed current at that point in a polarization curve where the electrode potential breaks over to the hydrogen overvoltage curve is equal to or greater than the local action current, it can be seen that the addition of the sodium chromate has reduced the local action or corrosion current by a factor of about 10.

Third—As might be expected, the film resistance should be greater in the case where the sodium chromate is present and this is shown by the curves of film resistance. It can be seen that the film resistance is not a constant value, but varies with impressed current. It is possible also to imagine a continual sloughing off and repairing of the film so that the resistance would fluctuate with time.

Anodic polarization curves were run also on these two systems, but for simplicity these are omitted in the graphs. There seldom is a pronounced break in the anodic curve in systems of this kind, but rather a gradual increase in slope.

These data illustrate the complete operation of the Pearson Bridge circuit. Several systems, including sodium nitrite, sodium molybdate, and other inorganic inhibitors have been run. Cross and Hackerman[2] have published data on some organic water soluble inhibitors using techniques similar to those described above.

Figure 4 shows a front view of the apparatus, with the AC current supply at lower left, DC current supply at lower right, AC null circuit at upper left and DC null at upper right.

Technique With Oil Phase Carrier

In studying oil soluble inhibitors in this laboratory, it was necessary to include an oil phase as the carrier for the material. In order to provide contact between the metal electrode and the inhibitor two methods were employed. With a layer of salt water and crude oil containing the inhibitor under test in the cell assembly, the metal electrode was first allowed to stand in the crude oil layer for varying lengths of time, then lowered into the salt water layer for a test run. In other tests the two phases were stirred with a magnetic stirrer to form an emulsion, then allowed to separate so that the metal was in the salt water layer for a test run. It is thought that the latter method gives more nearly a representation of what the metal would actually be subjected to in a well.

Figure 5 shows a close up of a test cell assembly mounted on a magnetic stirrer. The reference electrode at the right is connected to the electrolyte by means of an agar bridge, the end of which is turned upward to prevent crude oil from forming an impervious barrier when the system is stirred. The metal electrode is seen as a loop at the left of the cell, with the platinum electrode behind the agar bridge.

Regardless of the mechanical set up it soon became apparent that quite a different type of curve was obtained where polar organic inhibitors were present in the crude oil phase. After allowing time for adsorption to take place a very slight change in the impressed current gave a relatively large shift in electrode potential. In these cases some changes in technique were found to be necessary. In the first place it was unnecessary to balance bridge X_1-X_2 with AC because the solution resistance, R_s, was extremely small compared to an apparently large resistance at the electrode boundary. Certain types of adsorbed films were found also which did not exhibit the capacitance effect of by-passing the film resistance. It was found also that within very narrow limits the plot of impressed current vs electrode potential was a straight line through the zero current axis. When certain limits were exceeded (usually in the order of one to two μA per apparent sq. cm.) the curve was no longer a straight line. Figure 6 shows an example of this.

In this test a steel electrode was immersed in a system consisting of half sour crude and half salt water, both from an untreated, corrosive sour crude well. The crude phase contained 0.1 percent of inhibitor I. The curves show measured electrode potential vs impressed current for two times of contact with the system: A—2 hours and B—20 hours. In both cases, points on the cathodic side and anodic side were run alternately. Between +1 and —1 μA the curve is practically a straight line, but with current values greater than this a discontinuity occurs. This is thought to be due to dislodgment of the film by the higher current densities. In fact, when the current is stepped up greatly beyond the values shown in Figure 6, the curve reverts back to that of a typical corroding electrode and the zero current potential shifts from about —.550 mv. as shown here to around —.740 mv. which as was seen previously was the potential of a steel electrode in uninhibited salt water.

For comparison, curves for another inhibitor are shown in Figure 7. This inhibitor (II) shows a steeper slope and it is also interesting to note that it shows greater weight loss suppression in laboratory weight loss tests than does inhibitor I. Several dozen oil soluble inhibitors have been screened in this manner and although it cannot be reported that in all cases the suppression of weight loss is a function of the slope of this curve, it is a fact that without exception, all inhibitors which do show good weight loss suppression give a fairly high value for ΔE/ΔI. The converse is equally true, i.e., those oil soluble materials which give either low protection or none at all in weight loss tests produce a curve, when run in this manner, which is horizontal or nearly so.

Pursuing this relationship into field trials, all of the eight oil soluble materials now used in the field by the author's company produce a curve with a steep slope similar to those already seen and all are performing quite satisfactorily. In addition, two materials which were used in the field before starting tests of this type were condemned after prolonged tests in the field. Tests run since then show that neither material gives satisfactory weight loss suppression and both give a curve of ΔE/ΔI which is horizontal, showing a zero value. Numerous experimental compounds of unknown value have been screened and without exception the impressed current tests agree with weight loss tests.

Data Useful in Screening

It is obvious that there is some relationship between inhibitor efficiency and the slope of this curve. Although the relationship is not quantitative, it is at least qualitative and therefore of value in screening materials.

In order to study the inhibitor mechanism further, it is informative to reduce the technique to its simplest form and express the straight line portion of the curve as a slope, ΔE/ΔI, which by definition is ohmic resistance. The fact is recognized that this potential drop across the electrode boundary consists of elements other than a simple IR drop, but this need not be a matter of concern here. One of the principles

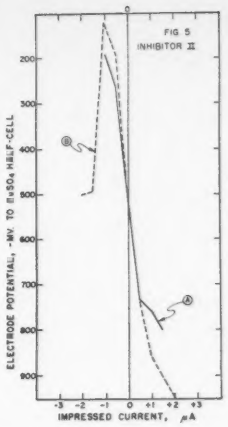

Figure 7—Same system as Figure 6, Inhibitor II.

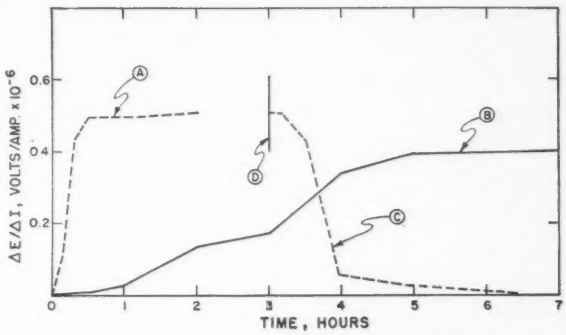

Figure 8—(ΔE/ΔI) vs time for two inhibitors. A shows rapid adsorption, B slow adsorption. Electrode removed to a fresh inhibitor-free environment at point D. Curve C shows falling off of (ΔE/ΔI) with time.

brought out in Pearson's original paper was that E_a and E_c may not be true constants but may actually be slowly changing functions of the applied current. The slope of this curve actually is equal to the film resistance plus the rate of change of polarization with current, or

$$R + \frac{\Delta e}{\Delta I}$$

where e is the true polarized potential of the electrode.

It is desirable, therefore, to set up a series of tests whereby the change in electrode potential can be determined between +1 and —1 μA, plotting this slope as a function of time of immersion. This value builds up to a maximum for each concentration of inhibitor and it can be assumed that when this maximum is reached, complete adsorption has taken place.

Such a test run is shown in Figure 8. Curves A and B show the results of tests on two inhibitors. As can be seen, inhibitor A adsorbs very rapidly, giving a maximum ΔE/ΔI after only 30 minutes. Inhibitor B takes about five hours to give a maximum value. Weight loss tests run under identical conditions of concentration and percentage of crude oil for 24 hours show that inhibitor A gives about 98 percent protection, whereas inhibitor B gives about 80 percent protection. Since five hours is about 20 percent of 24 hours it can be assumed that once the film has been completely adsorbed, full protection is obtained,

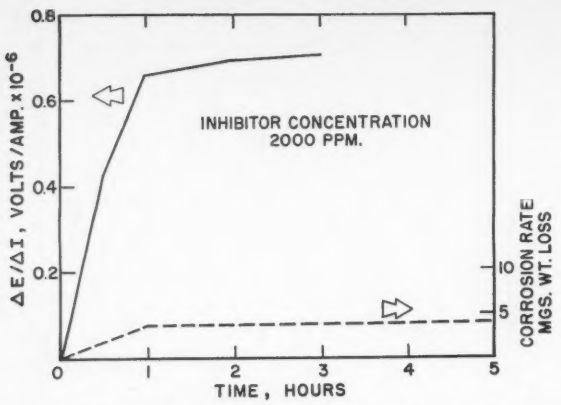

Figure 9—Curves showing adsorption and weight loss tests run in identical systems. For weight loss tests five systems were set up simultaneously and a coupon removed every hour. Inhibitor concentration 2000 ppm.

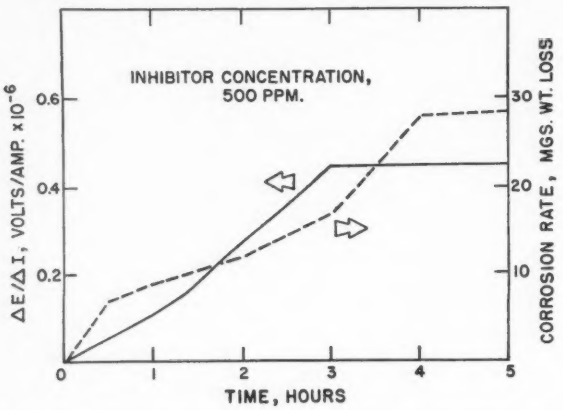

Figure 10—Same type tests as in Figure 9 with inhibitor concentration 500 ppm. Curves for weight loss follow fairly closely the slower adsorption time of the inhibitor at this lower concentration.

whereas corrosion is taking place (possibly at a decreasing rate) up to the time of complete adsorption.

Longer Adsorption Time Noted

In certain cases, an even longer adsorption time has been noted, sometimes up to 12 to 15 hours. The significance of this information has served to enlighten the evaluation of certain inhibitors which show up poorly on 24-hour weight loss tests, because it is felt now, at least in some cases, that this is due to the prolonged adsorption time. In a long range test the effects of the initial adsorption time become less important and certainly in a field test where inhibitor is constantly being replenished, this time is insignificant. A few compounds which at first were classed as doubtful by weight loss tests since have been shown to be slow adsorbers.

If the electrode and its adsorbed film are removed at some point D, and placed in a system containing no inhibitor, presumably the adsorbed film starts to break down and because there is none in solution to replace that which breaks away, note, as in Curve C, a falling off of film resistance with time. In general the desorption rate curve follows the adsorption rate curve, but it has been found that in certain instances adsorption takes place in a matter of a few hours whereas the desorption is a matter of days. One such inhibitor is now being tested in the field. Studies of this type may have practical significance in determining the frequency of treatment of an oil well. It would seem that the longer an inhibitor film remains unbroken without the necessity for repair or replacement, the less frequently it would have to be replaced in a producing well.

Another set of data which bears out the relationship between corrosion rate and adsorbed film resistance is shown in Figures 9 and 10. Figure 9 shows an inhibitor at a fairly high concentration, 2000 ppm. (in the oil phase); maximum film buildup occurs in about an hour. Multiple weight loss tests show that all of the corrosion occurs during the first hour, with no additional weight loss up to five hours. The same inhibitor at a lower concentration, 500 ppm, shows in Figure 10 a slower adsorption rate, building up to a maximum in about three hours. The corrosion rate remains fairly constant during the first four hours and then drops off to zero.

These tests show that there may be actually a quantitative relationship between this type of test and weight loss tests, but further work is needed to substantiate this. Some of the anomalies noted may be explained as more work is done on the relationships described and others which may be found.

Attempts to demonstrate films of high ohmic resistance with water-soluble organic inhibitors have been generally unsuccessful and most effort so far has been in the field of oil soluble materials. There is evidence to support the theory that at least some of the inhibitors studied actually must combine with the crude oil or some component of the crude oil to form the barrier films on metal surfaces. For example, experiments using kerosene and benzene as the carrier for the inhibitor usually fail to show the presence of such a film. Some materials will form a film in a system containing hydrogen sulfide brine and sour crude but not in a sweet crude system.

This brief review is intended to present a survey of methods and approaches and not the results of inhibitor testing. The complete practical significance of these various approaches is not yet apparent. While the relationships are interesting and sometimes quite illuminating in their insight into the way an inhibitor functions, it is obvious that the types of data obtained so far are not sufficient to give the complete story on inhibitor evaluation. At present field tests are being carried out on several types of inhibitors as characterized by these studies. For instance, one which adsorbs and desorbs very rapidly is being tried in the same field with one which adsorbs and desorbs slowly. The gathering and evaluation of data from field tests is a very slow process and conclusions cannot be reported at this time. It is hoped, however, that correlations between field and laboratory tests can be reported at some future date.

References

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2. Barton L. Cross and Norman Hackerman. Inhibitor Evaluation by the Pearson Null Bridge. *Corrosion*, **10**, No. 11, 407-412 (1954) Nov.
3. Müller. *Trans. Electrochem. Soc.*, **76**, 84, (1939).

Control of Internal Corrosion Of a Products Pipe Line System*

By P. L. DeVERTER and A. W. JASEK

Introduction

WHEN PRODUCT PIPE LINES first came into use, it was perhaps assumed that problems in their operation would not differ materially from those experienced in the operation of crude oil or natural gasoline pipe lines. Internal corrosion in natural gasoline pipe lines, to the knowledge of the authors, does not present any serious control problems. Crude oil pipe line operators controlling internal corrosion are concerned primarily with protection of capital investment and prevention of leaks, whereas controlling internal corrosion in product pipe lines includes maintenance of product quality as a matter of equal importance. Internal corrosion and its control in a products pipe line present problems of an entirely different nature and of no small magnitude.

Description of Baytown-Irving Products Line

A 275-mile single 8-inch products pipe line was placed in operation late in 1946 and up to this time has handled regular and premium automotive gasolines and 100 and 115 octane grades of aviation fuels. The system is equipped with Moorelane type strainers and hay tanks. Figure 1 indicates the layout of the line.

History of the Inhibitor Program

Before the operation began, a study was made to determine what control would be used to prevent internal corrosion of the system. A water soluble inhibitor process was selected, but as was common practice at that time, the inhibitor treatment was delayed for one year so the mill scale would break loose and could be removed. It is not believed delaying the use of an inhibitor has been beneficial in any respect and based on experience it is apparent use of a corrosion inhibitor should begin immediately after a new line has been put in operation.

Water Soluble Inhibitor Used

During the first year of operation the system was scraped often and much difficulty was had with mill scale and rust. As a matter of fact, the system was completely plugged on a few occasions. Late in 1947 injection of the water soluble inhibitor was begun at both Baytown and Hearne stations. The line condition then showed a slow but continual improvement. However, frequent scrapings were required and much difficulty was experienced in filtering the takeoff streams at the four terminals. Filtering difficulties were, of course, more severe when scraper heads arrived. However, the filtering problem persisted even when no scrapers were being received. The water soluble process was continued for approximately four years, during all of which time the pH of the effluent water was maintained as recommended by the originators. At the end of the four year period, the continued difficulties of filtering, servicing hay tanks and the need for frequent scrap-

★A paper presented at a meeting of South Central Region, National Association of Corrosion Engineers, Dallas, Texas, October 12-15, 1954.

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A. W. JASEK—Senior chemical engineer with Humble Pipe Line Company, Houston since 1951, where he is engaged in corrosion control and measuring, sampling and testing work. From 1945 to 1951 he worked for Humble Oil and Refining Co. as laboratory assistant specialist and as senior cargo inspector. He holds a BS in chemical engineering from University of Texas and is a member of NACE and American Chemical Society.

Abstract

This article considers the matter of controlling internal corrosion in a products pipe line system and reports experience with two control methods. A laboratory method of evaluating a particular oil soluble inhibitor is described, as well as the application of the laboratory method to control the degree of protection in the pipe line and to facilities beyond the pipe line. A specific method of determining the amount of inhibitor in the product also is discussed and proper interpretation of the laboratory data is emphasized.

Experience referred to covers the corrosion control in a single 8-inch products pipe line transporting only premium and regular grades of motor fuel and 100 and 115 grades of aviation gasoline. This includes use of a water soluble inhibitor for several years but because the degree of protection desired was not realized and because the protection ended at the pipe line terminus, decision was made to substitute an oil soluble inhibitor. Factors considered in selecting the oil soluble inhibitor included cost, effect on product specifications and the degree of protection desired both in the pipe line and to equipment beyond the pipe line.

Results indicate that benefits realized through the use of an oil soluble inhibitor more than offset its higher cost compared to the water soluble type. The article mentions briefly the attitude of the U. S. Air Force Materiel Command, which indicates the direction of general acceptance of the use of oil soluble inhibitors, at least in systems handling fuels for the U. S. Air Force.

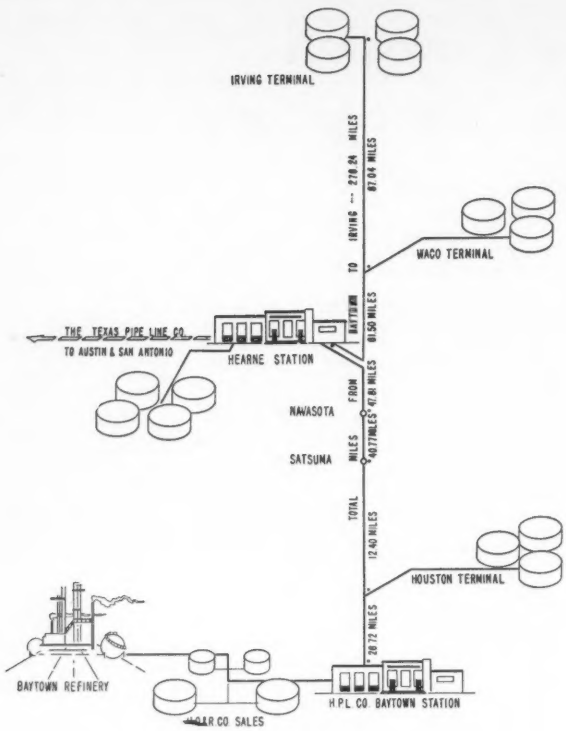

Figure 1—Baytown-Irving product system.

TABLE 1*

Appearance of Rod	Rating	Designation
Free of rust	Passes	R-1
Trace of few spots	Passes	R-2
Less than 5% surface rusted	Barely passes	R-3
5 to 50% of surface rusted	Does not pass	R-4
50 to 90% of surface rusted	Does not pass	R-5
Surface covered with light rust	Does not pass	R-6
Surface covered with heavy rust	Does not pass	R-7

(A typical report would read: Rust Test—Passes R-2.)
* P. L. DeVerter, Test for Presence and Evaluation of Product Soluble Rust Inhibitors, *Petro. Eng.*, Sept., 1953.

ings (approximately two scrapers each week) indicated rather conclusively that the water soluble process was not preventing corrosion to the degree desired.

The continued high cost of filtering and scraping, coupled with frequent complaints from our customers, led Humble Pipe Line to consider other methods of controlling internal corrosion.

Methods of Controlling Internal Corrosion

Proper consideration must be given to the selection of a method of controlling corrosion which will not have any adverse effects on product specifications. Likewise, the question of economic feasibility of the method must not be overlooked. There are three widely used methods of reducing and controlling corrosion, each of which has some merits as well as demerits. However, it is not the purpose of this article to give a detailed description and comparison of the three methods.

Internal corrosion can be reduced by dehydrating the product by passing it through a bed of activated alumina. The dissolved water is removed from the fuel until the "dew point" of the fuel reaches a temperature about 5 F below the lowest temperature encountered in the line. The high initial capital investment required for dehydration equipment and the cost of subsequent maintenance and operation of the equipment makes this method of reducing corrosion unattractive when compared to other methods.

The use of water soluble inhibitors is a comparatively cheap method of comtrolling internal corrosion. However, this method presents certain problems. The authors' company's experience in the use of a water soluble inhibitor leaves something to be desired. The cost of the materials and patent rights of the water soluble process is inexpensive compared to other methods but there is concurrent cost of running scrapers, reinhibition in a long line and filtering the product as it leaves the system. Protection achieved through the use of water soluble inhibitors is limited to pipe line equipment and no inhibition is afforded facilities before or after the pipe line.

More recently favorable results have been obtained with oil soluble inhibitors which have several attractive features, giving them a versatility not possessed by the other methods. This type of inhibitor prevents corrosion by depositing a thin protective film on the pipe wall which acts as a diffusion barrier between the steel and the attacking corrosive agents. The outstanding advantage of this type of inhibitor is that protection travels along with the product until the product is consumed.

Details of Laboratory Investigations

Early in the program of studies of oil soluble inhibitors authors were confronted with the need for a laboratory method of evaluating the corrosion preventing properties of various oil soluble inhibitors which would indicate their performance in a products pipe line.

Several procedures were made available by other laboratories which were found to be time consuming and not to meet particular requirements of the inquiry. A rust test procedure was devised by the authors' company's inspection laboratory with which reproducible results could be obtained in approximately one hour. By the use of this rust test, the effect of a given sample of gasoline on a polished steel rod could be determined and by varying the concentration of a particular inhibitor, the degree of protection afforded the steel rod likewise could be determined. Procedure finally developed by the laboratory was published in September, 1953 issue of *Petroleum Engineer*. The rating schedule is shown in Table 1.

Some difficulty was experienced with obtaining reproducible results. This trouble finally was localized in the steel rods. It was found that the SAE 1020 rods available from suppliers were not satisfactory. The rods finally selected for use were prepared from concrete reinforcing rods. (ASTM-A15). The NACE TP-2E Committee on Internal Corrosion of Product Pipe Lines currently is investigating the rusting tendency of various types of steel for the purpose of having a number of steel coupons made up from a single batch of suitable steel. The coupons will be distributed to various product pipe line com-

panies to be installed in their lines for the purpose of evaluating inhibitor efficiency in controlling internal corrosion.

The laboratory rust test has been found satisfactory for comparing effectiveness of inhibitors; and, for a known inhibitor, to give an indication of the concentration present. This test also is used for control information on dosage for desired protection. It must be emphasized that proper interpretation of the laboratory data is essential, in order to correctly correlate laboratory and field data.

Quantitative Laboratory Test

Authority to use an oil soluble inhibitor in aviation gasoline was secured from the U. S. Air Force before the use of an oil soluble inhibitor was initiated in the reported system. The Air Force requested that a method of detecting the amount of rust inhibitor added to gasoline be developed. A procedure was developed by Humble's Research Division which is specific for the oil soluble inhibitor now being used in aviation gasoline. The method consists of washing out the acidic material with alkali, neutralizing, acidifying and extracting with carbon tetrachloride. The concentration of the acid, as a measure of inhibitor content, is determined by infra red absorption.

Requirements for an Oil Soluble Inhibitor

A satisfactory oil soluble rust inhibitor should first of all be effective in controlling internal corrosion in a pipe line. It should be economical and safe to use. The inhibitor should be stable and render a type of protection that travels along with the product until the product is consumed. It must be compatible with the product in which it is used and have no adverse effects on product specifications. It should have a relatively high active ingredient content, because a low content requires a higher dosage than is desired.

In the authors' opinion, aviation gasolines and jet fuels are critical products in which to test an inhibitor. Effect on the following specifications must be ascertained: ASTM Gum, Accelerated Gum, Corrosion (Copper Strip), Color, Final Boiling Point, Water Tolerance Test.

Authors have set a maximum of 1 mg increase in the gum tests as the limit of acceptability as some slight increase is to be expected. The copper strip corrosion test should show no increase in corrosivity.

The Final Boiling Point or other required distillation points should not be materially affected by the inhibitor. Close limits are set on the color standards of aviation gasolines by the military and some inhibitors seriously affect one or more of the dyes. There should not be more than a slight effect on the color of inhibited product so that it will be acceptable to government inspectors. The water tolerance test is a military requirement and some inhibitors which pass most all other requirements do not pass this test.

One other factor is now being considered by the military, to determine if such inhibitors affect accuracy of capacitance gauges used in aircraft fuel tanks. However, it is doubted that in the concentrations used any of the inhibitors will affect the operation of such gauges.

TABLE 2

Inhibitor	Dosage (Active) Pounds	CD Gum	Accelerated		HIL Rust Test	Color
			Gum	Ppt.		
None.....	None	.8	.4	Nil	R-7	Green
C.....	3	1.4	.8	Nil	R-2	Satisf.
L.....	3	1.8	2.0	Nil	R-1	Borderline
D.....	2	1.6	2.8	2.2	R-1	Satisf.
S.....	5	9.1	4.2	Nil	R-1	Sl. darker
A.....	2	1.2	1.4	Nil	R-2 Emulsion	Satisf.

TABLE 3

	C Factor	Scrapers Per Year	Wool Felt Filter Changes/per Mo.
Water Soluble 1947 to March, 1952.....	156 to 158	120	400
Oil Soluble March 1952 to Aug., 1954..	159 to 163	10	75

While a large number of different types of oil soluble inhibitors from many different suppliers were evaluated in the laboratory, tests indicated that only a few would satisfy requirements for use in a products pipe line. From literature, patents, analysis and information supplied by manufacturers, it appears there are four general types of compounds presently used in oil soluble rust inhibitors. These four types could be classified as petroleum mahogany sulfonates, polymerized fatty acids, organic amines and organic phosphorus compounds. In the authors' opinion, most inhibitors on the market are a mixture of two or more of the above types.

Table 2 shows a few pertinent tests on inhibitors represented by these types. The type of inhibitor is not identified but indicated by a code letter.

The mechanism of corrosion inhibition is not known definitely. Some ascribe the inhibition to chemisorption,[1] others to chemical action of polar[2] or semi-polar compounds. In a recent Wright Air Development Center report[3] it is stated that "nearly all of the investigators agree that an oriented adsorption of the effective molecule occurs in some manner to prevent attack on the metal by moisture, oxygen, etc. In addition metals also can be protected against corrosion by means of a barrier system which mechanically prevents contact by corroding atmosphere. It should also be possible to have corrosion inhibition by a combination of a barrier and an oriented absorbed molecule. The organic compound by itself may not be an effective inhibitor nor the oil an effective barrier but in combination they may be effective in inhibiting corrosion."

The latter effect refers to synergistic combinations which are quite common in other types of inhibitors. Consequently, it is the authors' opinion that mixtures of two or more of the basic types of rust inhibitors are used in most commercial products.

Field Observations on the Use of Oil Soluble Inhibitors

1. *The Effectiveness of Oil Soluble Inhibitors*

The authors' experience indicates conclusively that by using proper concentration of certain oil soluble inhibitors internal corrosion of product pipe lines

may be controlled effectively. This conclusion is supported by both laboratory data and field tests, including rust tests on samples of gasoline taken from various points in the system, as well as from filling stations in some of the operating areas served by the system. The conclusions are substantiated further by the marked improvement indicated by the reduced filtering maintenance and by a substantial reduction in the number of scrapers run through the system.

Further effectiveness of an oil soluble inhibitor in the system is indicated by a noticeable increase in pumping rates borne out by C-factors in the neighborhood of 159 to 162.

Table 3 indicates the improvement in C factor, scraper and filter reduction.

2. *Scraping Operation*

Scraper runs have been reduced at least 10-fold since starting the use of an oil soluble inhibitor. Where the water soluble inhibitor was being used 120 scrapers per year were required. Experience after two years of oil soluble inhibition indicates that only 10 scrapers per year will be required. Also, the amount of foreign material received with each scraper now is no more than and in most cases less than it was when the scraper frequency was 120 per year.

3. *The Cost of Oil Soluble Inhibitors*

Cost of materials used to inhibit a products pipe line is considerably less when water soluble inhibitors are used, even though the water soluble inhibitor is injected frequently at more than one point in the system. When protection is desired for facilities other than the actual pipe line, namely refining delivery lines to the pipe line, storage tanks, meters, tank trucks, filling stations and other equipment beyond the pipe line terminus, the overall savings effected by the use of an oil soluble inhibitor should be considered. In many cases the overall savings effected by the use of an oil soluble inhibitor will perhaps offset its greater cost by a considerable margin.

4. *Control Degree of Protection*

When injection of an oil soluble inhibitor is begun, a maximum injection rate will be required for a short period to permit the inside surface of the pipe to become coated or plated. During this period the concentration of inhibitor at the terminus will be considerably less than the concentration at the origin. Concentration used and the time required to completely protect the system will vary depending upon the condition of the pipe at the beginning of the program. Furthermore, rust removed from the pipe wall will use up the inhibitor and make it difficult to estimate this time element.

When the point is reached that the concentration at the terminus approaches the concentration at the origin, the inhibitor injection rate can be reduced materially if protection is desired for pipe line equipment only. Should protection be desired for customers' facilities, terminals, transport trucks, filling station storage tanks and consumers' automobiles, more inhibitor may be required.

On the other end of the system, the receiving end, receipts from the refinery move through appreciable piping and this piping, likewise, should be protected.

Based upon experience reported here it is recommended that a single injection of oil soluble inhibitor be made at a point in the refinery which will permit the protection of as much tankage and delivery equipment as possible, including the delivery line from the refinery to the pipe line suction.

In the instance reported here the extent and degree of protection is controlled more or less by the use of the laboratory rust test procedure. Present procedure is to test every batch of gasoline entering the system and only the aviation gasoline delivered at the end of the system. Injecting the inhibitor at the rate of two quarts per 1000 barrels of gasoline provides a rust rating of R-2 on all gasoline entering the system, and a R-2 and R-3 on gasoline delivered at the end of the system. This experience indicates that this is a satisfactory method of controlling internal corrosion in a products pipe line. It must be emphasized that the proper interpretation of the laboratory data is essential to obtain a proper correlation of the laboratory and field data because the laboratory test method does not reproduce exactly the conditions encountered in the line. The laboratory procedure sets up conditions that are considered to be more severe than conditions encountered in the line, therefore gasoline delivered at the end of the system which has a rust rating of R-3 is considered to contain sufficient inhibitor for pipe line protection.

5. *Effect of Initial Use of Oil Soluble Inhibitors*

Initial use of an oil soluble inhibitor is accompanied by a considerable increase in the amount of corrosion products (rust and will scale) in the product delivered at the take-off terminals.

These investigations indicated that a system should be scraped frequently in the beginning of such an inhibiting program to permit removing the mill scale as it breaks loose rather than allow too much mill scale to break loose before a scraper is run and increase the danger of plugging the line. It is further recommended that, where possible, the dirty stream ahead of a scraper be diverted to a settling tank rather than to attempt to move it through filtering equipment. After the dirty product is settled most of the product can be recovered. Cone bottom settling tanks are particularly adaptable to this operation.

6. *Foreign Material in Pipe Line Receipts*

During the past few years large quantities of sediment composed of fine rust and chemical silt, sometimes with a sticky or gummy consistency have been removed from the system by scrapers, filters, hay tanks and slop tanks. Chemical analysis of this sediment indicates it is mostly lead and iron mixed with carbonaceous material. Frequently the content of lead is 10 to 15 times as great as the iron content. Sediment of this general description is foreign to the corrosion chemistry of a product pipe line system, indicating that a considerable portion of the foreign material was perhaps of refinery origin rather than the result of internal corrosion within the pipe line.

In order to obtain a true perspective of the internal corrosion problem, any corrosion study should in-

clude determination of the amount and type of sediment carried in the products stream being received from the refinery. Filtration tests of products being received from the refinery at a point upstream from the inhibitor injection equipment were made in the inquiry reported here and it was found that the stream contained a considerable amount of sediment of refinery origin. Much of this sediment has a particle size of less than 40 microns and will pass through felt filters at the initial station. It is further believed that perhaps these particles would grow in size due to both line pressure and adsorption of the inhibitor on the surface of each particle of sediment. The enlarged particles then would have a greater tendency to drop out in the line and increase filtering and scraping expense.

It was discovered that the stream being received contained from 5 to 10 pounds of sediment per 1000 barrels. The delivery line from the refinery approximately two miles long never had been inhibited and the first step was to move inhibitor injection equipment to the refinery pump location. Efforts were made to schedule pumpings from the refinery to permit as much settling time as possible in the immediate storage tanks into which the refinery delivers and from which suction is taken.

Attempts also were made to make personnel more conscious of the importance of minimizing the amount of water put into the system as well as water or foreign material from sump tanks. Cone bottom settling tanks have been provided into which all sump tank material is transferred to permit water and sediment to be drawn off the bottom of the cone before the sump products are pumped into the system.

The above changes in operating procedure had a sudden and marked beneficial effect on the amount of sediment actually moving into suction. This underlines importance of making a thorough check to insure that the receiving stream from the supplier is as clean as possible and it is not being contaminated by sump tank procedure.

7. Conclusions

Conclusions after over two years' use of an oil soluble inhibitor can be summarized as follows:

1. Oil soluble inhibitors have proved to be effective as anti-rust inhibitors for pipeline use. Such inhibitors are feasible from standpoints of economics, permanency and benefit to all types of transportation, storage and dispensing equipment. It is estimated the amount of mill scale, rust and other solid material filtered out since using an oil soluble inhibitor has been reduced 85 percent.

2. The inhibitor selected should be thoroughly evaluated in the laboratory to determine the effect on product quality. The nature of the tests required will be determined by type of product delivered through the pipeline.

3. If possible, it is desirable to develop a quantitative laboratory test for the particular type of inhibitor used. Some customers (especially the military) are interested in a verification of the dosage used.

4. Oil soluble inhibitors are advantageous in that no water is added to the pipeline system, only one injection is required, pumping capacity is increased and filtering operations and scraping schedules can be reduced.

Acknowledgment

Authors express their appreciation to management for the opportunity to present this paper and to L. S. Wrightsman, who assisted in the preparation of the material.

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DISCUSSION

Comments by R. S. Treseder, Shell Development Co., Emeryville, Calif.

I should like to point out that the experience of the authors with a water soluble inhibitor represents an unusual case. My company and others have used sodium nitrite, a water soluble inhibitor, with considerable success for periods up to 15 years. This successful use of sodium nitrite has been reported in detail in several technical articles.[1]

It is interesting to note that a number of the recommendations arrived at by the authors following extensive field testing of an oil soluble inhibitor parallel recommendations for use of sodium nitrite. These recommendations are:

1) strong initial inhibitor treatment with frequent scraping of the line, particularly where the line is already rusted,
2) injecting the inhibitor as close to the refinery source as possible,
3) avoiding contamination, particularly contamination with salt water,
4) careful and continuous control of inhibitor concentration at both ends of the line, and
5) if inhibitor injection is interrupted for any significant period of time, repeating the strong initial treatment and frequent scraping.

We would recommend strongly against allowing a new line to rust prior to start of inhibition. The presence of rust in the line leads to consumption of inhibitor and loss of protection. To counteract the effect of existing rust, it is necessary to inhibit with stronger and more frequent doses and to scrape frequently to clean out the line. The net result of delayed inhibitor treatment is greater difficulty in achieving satisfactory inhibition.

The advantage commonly quoted for a gasoline soluble inhibitor to compensate for its higher treatment cost as compared to water soluble inhibitors is the protection of equipment beyond the pipe line terminal. Do the authors have any experience information that would indicate the order of magnitude of

savings in maintenance of such equipment resulting from use of a gasoline soluble inhibitor?

During further discussion on this paper, the following comment was made in response to a question from the audience, "In comparing the economics of water soluble and oil soluble inhibitors, it should be remembered that, with the water soluble inhibitor, it is necessary to inhibit one part of water in contrast with the 40,000 parts of gasoline that must be inhibited with a gasoline soluble inhibitor."

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4. S. S. Smith and R. K. Schultz. *API Proc.*, **24,** part IV, 91-101 (1943).
5. Ivy M. Parker. *API Proc.*, **26,** part V, 26-26 (1946).

Reply by P. L. DeVerter:

We certainly are in agreement with Mr. Treseder's recommendations outlined in his comments. We would like to point out that we are not the only company that has changed from a water soluble inhibitor to an oil soluble inhibitor with increased benefits.

Our customers admit there is some protection afforded to equipment beyond the pipe line. Rust tests on gasoline delivered at the end of the line indicate sufficient inhibitor remains in the gasoline to give an R-2 rust test rating. The pipe line is not in a position to completely evaluate the protection afforded to equipment beyond the pipe line by the use of an oil soluble inhibitor. We do know that we are delivering a cleaner product, filtering requirements have been reduced, meter maintenance has been reduced, which in turn has increased over-all accuracy in measurement.

Comments by Ivy M. Parker, Plantation Pipe Line Co., Atlanta, Ga.:

1. Was there a change in ratio of lead-to-iron in scale when you changed from water soluble to oil soluble inhibitor?
2. Were there any changes in operating procedure which may have coincided with change of inhibitors?

I am at a loss to understand why this operator obtained such poor results with their water soluble inhibitor as I am confident that their control of inhibitor injection was good. We feel that it is a mistake to delay the inhibitor program. It should be started as soon as the line is filled with product. We placed a new 80-mile section of 14-inch line in operation last winter which we inhibited very heavily with sodium nitrite while filling the line and for the first few months of operation. We have obtained very little heavy scale and the line has an excellent efficiency, based on C-Factor.

Reply by P. L. DeVerter:

1. We do not have sufficient data on analysis of material removed from the line to give a reliable answer to this question. The data we have indicate some change in the ratio of lead to iron. However, after changing inhibitors, there was a noticeable increase in an organic type material removed from the line.
2. There has been no change in operating procedure except that there has been a 10 percent increase in products pumped from Baytown since we started using an oil soluble inhibitor. This has made it necessary to pump larger batches, resulting in more frequent over and short pumping from the refinery.

Any discussions of this article not published above will appear in the December, 1955 issue.

Corrosion Studies on a Model Rotary Air-Preheater *

By G. G. THURLOW*

Abstract

Tests have been carried out on a model rotary air heater in an attempt to study, on a laboratory scale, corrosion phenomena under conditions similar to those experienced in industrial practice.

The acid dew-point of the combustion gases used varied from 240 to 320 F and maximum corrosion occurred at surface temperatures within the range 215-240 F. The results confirm previous conclusions as to the influence of the acid dew-point and of the sulfur trioxide content of the gases on corrosion.

Introduction

WORK CARRIED out on behalf of the Boiler Availability Committee[1] has established that the corrosion occurring in air heaters of power station boilers is generally due to the action of sulfuric acid condensing from the flue gases. Tests on full-scale installations using, among other instruments, air-cooled metal probes (Thurlow 1952),[2] have provided quantitative data on the relation between corrosion and surface temperature and confirmed that there are several factors, especially dust loading in the gases (Corbett and Flint 1953), which influence the degree of corrosion; whilst laboratory investigations, under controlled conditions, have shed more light on the mechanism by which corrosion occurs both in clean gases (Flint and Kear 1951) and in the presence of carbon smokes (Kear 1951).

These earlier laboratory investigations carried out by Flint and Kear employed a system in which a steel hemispherical surface of limited area was inserted into laboratory gases containing sulfur trioxide, for periods of up to one hour, and attention was focused on the relative importance of dew-point and metal temperatures. It was thought, however, that as the conditions in such experiments departed considerably from those in practice, interpretation of the results with respect to full-scale practice was correspondingly limited. The present series of tests has been carried out to repeat this earlier work under conditions more representative of practice and to extend it in the light of later experience. Use was made of a model rotary preheater, initially constructed within the British Coal Utilisation Research Association (BCURA) for fundamental heat transfer studies. Apart from aerodynamic considerations, this also had the advantage over a small probe that its design facilitated the removal and analysis of corrosion products at various intervals during a run.

Experimental Apparatus

Basis of Design of Model. Tests on full-scale industrial installations and laboratory investigations both present certain inherent difficulties: testing on full-scale industrial installations is expensive, owing to the large amount of instrumentation needed, and complicated by the necessity of following the day-to-day operation of the plant, whilst in the laboratory it is difficult to represent adequately the conditions existing in full-scale plant.

In an attempt to eliminate some of these disadvantages, a model air heater was built that would have as nearly as possible the same aerodynamic and temperature properties as a typical full-scale rotary air heater used on power station boilers. In this design of regenerative heater, the heat is transferred by means of steel elements set in a rotar that revolves slowly in a casing; the flue gases are directed axially through one side of the rotor while the air passes, generally in the reverse direction, through the other. The elements of the rotor act as heat accumulators, absorbing heat on passing through the hot gas, storing it, and giving it out on passing through the air. The heat flow characteristics of the model were determined and its performance was found to be in general agreement with that predicted from approximate theoretical solutions based on recuperator theory. It was found that heat storage in the element plates was not important above rotor speeds of about 1 rpm, and that, at rotor speeds used in practice, the heat transfer coefficients between the fluids and the metal could be calculated easily. This earlier work, summarized elsewhere (Thurlow 1951), is of more interest owing to the techniques involved than to the rather limited data obtained. It was demonstrated, however, that the thermal cycle undergone by the element plates and the average metal temperatures obtained on the model were similar to those obtained in practice. It has been assumed that the temperature conditions between these earlier tests and those reported here were sufficiently similar, in spite of some modifications carried out on the model since the earlier work. These modifications made the plates easier both to manufacture and to remove from the unit. On these heaters, the plates undergo a cyclical fluctuation in temperature as they revolve through the gas and air stream respectively and, in order to eliminate any effects of this, a speed of rotation was chosen at which the variation was small enough to be neglected. As the influence of the aerodynamic conditions on corrosion rate is not certain, no attempt has been made at this stage to simulate the influence of this on the model. The Reynolds numbers of the

TABLE 1—Dimensions of Full-Scale and Model Heaters

	Full-scale	Model
Diameter of rotor, feet	12	0·5
Length of rotor, feet	0·5	0·167
Plate thickness, feet	0·00256	0·00768
Heat transfer surface areas, sq. ft.:—		
Gas side	1,100	1·89
Air side	750	1·26
Whole rotor	2,400	4·08
Total area of fluid passage, sq. ft.:—		
Gas side	.....	0·041
Air side	.....	0·027
Mean hydraulic diameter of individual gas passage, feet	.....	0·0217
Surface area of test element, sq. in.	.....	8·4

★ Reprinted from *Proc. Inst. Mech. Eng.*, **168**, No. 20, 571-578 (1954). The MS of this paper was received at the Institution on the 10th of July 1953.

* A member of the research team, British Coal Utilization Research Association.

(1) The Boiler Availability Committee is representative of the Watertube Boilermakers Association, the British Electricity Authority, the Fuel Research Station and the British Coal Utilization Research Association.

(2) An alphabetical list of references is given in the appendix.

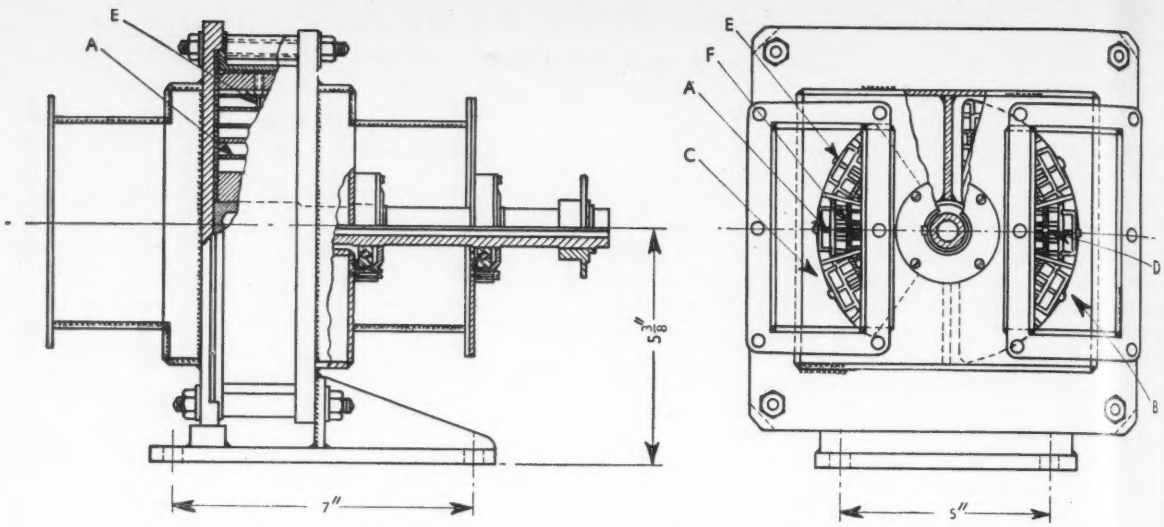


Figure 1—Details of model. A—Rotor. B—Flue gas passage. C—Air passage. D—Thermocouple. E—Locking pins. F—Test specimen.

gases in the heat transfer passages are lower than those generally attained in practice, though the actual gas velocities are higher.

The relevant dimensions of the model and of the full-scale air heater design on which it was based are given in Table 1.

Description of Model. The essential details of the model are shown in Figure 1. The heat transfer plates are packed in a rotor A which revolves round a horizontal shaft mounted on ball bearings. The rotor is enclosed in two casings designed to direct the hot and cold gases in contra-flow through opposite sides of the heater. The left-hand casing may be removed by undoing the holding bolts without disturbing the rotor. The rotor, which is divided into twelve equal segments each packed with removable mild-steel element plates, is driven at a speed of 7 rpm by a 230-volt AC motor through a reduction gear and chain drive. The end faces of the rotor, consisting of an outer and inner rim and radial sealing faces, bear on to stationary asbestos board seals to prevent leakage between the two gas passages. The analysis of the steel used for the air-heater element plates is given in Table 2.

A direct measurement of the temperature of the matrix was obtained by the use of a constantan wire which, sealed into the rotor at the position D shown, formed with the element plates a steel-constantan thermocouple, and was then taken out through the hollow core of the rotor shaft.

The gas temperature at entry and exit to both sides of the heater was measured by means of mercury-in-glass thermometers. These had been previously calibrated against thermocouple traverses across the ducts, and were found to be accurate within the limits of these experiments.

Description of Test Rig. The layout of the rig is shown diagrammatically in Figure 2. A supply of hot flue gas for the model A was obtained from a gas burner installed in a brick furnace E, the gases being collected in a metal hood and drawn through the heater by a suction fan C. This same fan was utilized to draw cold air, taken directly from atmosphere, through the cold side of the heater. The flow through the system was controlled by butterfly valves D inserted in the line as indicated, and measured by orifice plates E inserted before and after the heater on the air side and after the heater on the flue-gas side. The difference between the two readings on the air side showed the leakage between the two sides of the heater and, by adjusting the various valves to equalize the static pressure on both sides of the system, this leakage was kept to a minimum.

TABLE 2—Analysis of Steel Used for Matrix

CONSTITUENT	Percent
Carbon	0.16
Manganese	0.59
Sulfur	0.01
Phosphorus	0.04
Silicon	0.05

Sulfuric acid was added to the flue gas by dripping a dilute solution of it, at a constant rate, down a bent quart tube H, the bend of which was located in the flame as shown. The amount of acid entering the system was controlled by varying either its flow rate or its concentration, while the resulting percentage sulfuric acid in the flue gases was calculated from reading taken with a BCURA dew-point meter G (Corbett, Flint, and Littlejohn 1952) which was inserted into the elbow of the gas inlet pipe. In this instrument an AC potential is applied between two platinum electrodes set in the surface of a glass thimble. This is cooled by compressed air blown over its underside, and the electrical conductivity of any film condensing or collecting on the surface can be measured. The electrodes are in the form of thermocouples and are used for measuring the surface temperature. It has been shown that the dew-point temperature is a function of the acid concentration in the flue gas, while the rate of increase of the electrical conduc-

tivity of the condensing film is dependent on the quantity of acid condensing. This is further discussed later.

The position of the mercury-in-glass thermometers F are also indicated in Figure 2.

Experimental Technique

Flow conditions were kept constant throughout the investigation, the gas flow being equivalent to 0.046 lb. per sec. and the air flow to 0.028 lb. per sec. The air inlet temperature was between 65 and 75 F. The temperature of the heat-transfer elements was varied from test to test by changing the gas inlet temperature; this method being adopted as representing most closely the way this temperature varies in practice. A range of gas inlet temperatures from 350 to 500 F was employed. At the gas and air flow ratios used, the earlier heat-transfer work had shown the average plate temperature to be the mean of the average gas gas and air temperatures and this was confirmed by thermocouple measurements taken during these tests. At the speeds of rotation used, the change in temperature of the plates in passing through the hot and cold gases was about 5 F.

The variation of temperature over the test surfaces was of the order of ±15 F. Attempts to make more accurate assessments of this variation, using both thermocouples and temperature-sensitive paints, were inconclusive.

The parts of the heat-transfer elements used as test specimens were prepared by polishing with No. 1 and No. 00 emery paper, followed by careful wiping. They were fitted into a heater at the radial position shown in heavy black lines in Figure 1, after the apparatus had warmed up to steady temperature conditions. It was possible, therefore, to use up to eleven similar specimens in each test (the twelfth sector being fitted with the thermocouple). In the following investigation, either three or five of these possible specimens, evenly spaced round the rotor, were analyzed at each test. After the test specimen had been inserted, the temperatures throughout the system were allowed to settle again for another quarter of an hour before the acid drip feed was started. At the end of a test, the acid supply was turned off and the air heater was taken apart as rapidly as possible. The test specimens were removed and immediately washed with boiling distilled water. The washings were analyzed and the iron and sulfate content were determined gravimetrically as ferric oxide and barium sulfate respectively. Readings of the flow, temperature, and dew-point conditions were taken at regular intervals throughout the test.

During the long duration test (that is, up to 8 hours) the air heater was opened, a specimen was removed for analysis and a fresh element was put in its place at intervals throughout the run so as to obtain intermediate readings. This necessitated opening the heater for 3-4 minutes only and did not upset conditions to any appreciable extent.

Analysis of Results

It was possible to plot all the dew-point meter results on the one family of curves, relating the rate of increase of conductivity (expressed in units of micro-

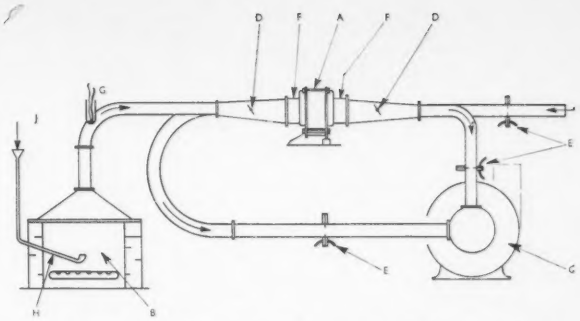


Figure 2—Layout of test rig. A—Air heater. B—Furnace. C—Suction fan. D—Butterfly valves. E—Orifice plates. F—Mercury-in-glass thermometers. G—Dew-point meter. H—Quartz tubing. J—Acid feed from constant head supply.

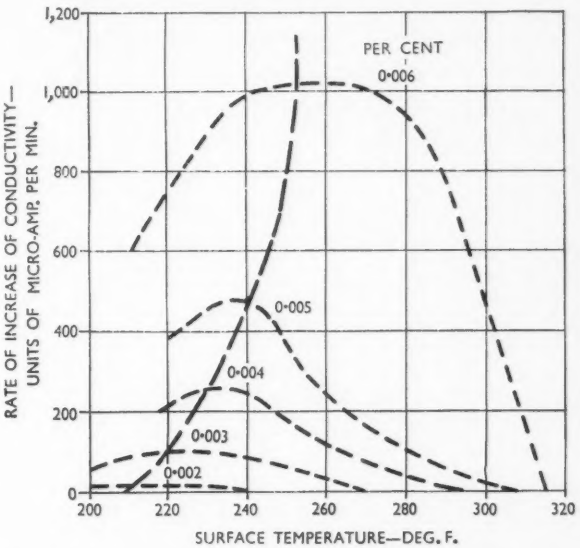


Figure 3—Summary of measurements made with dew-point meter. Relation between rate of increase in conductivity and temperature of condensing surface for different concentrations of sulfuric acid measured by volume of dry gas. — — Mean line relating maximum conductivity and surface temperatures.

amps per min. measured at an applied potential of 10 volts) to the temperature of the condensing surface for various acid concentrations in the flue gas, as shown in Figure 3. As the experimental curves were obtained in most cases at intermediate values of the acid concentration, it is not possible to show the experimental points on this figure. It can be stated that these results correlate well with the mean curves at the lower acid concentrations though, owing to an increase in the scatter of the results, the curves at the higher acid concentrations are somewhat less reliable. These results were obtained from runs with gas inlet temperatures from 350 to 500 F and illustrate, as has also been shown recently by Corbett, Flint, and Littlejohn, that the gas temperature has no appreciable effect on the rate of increase in conductivity.

The amounts of sulfate deposited and iron corroded during a set of 1-hour runs at various surface temperatures are shown in Figure 4 plotted against the concentration of acid in the flue gas. It will be seen that the reproducibility of the experimental results was, on the whole, good especially in view of the difficul-

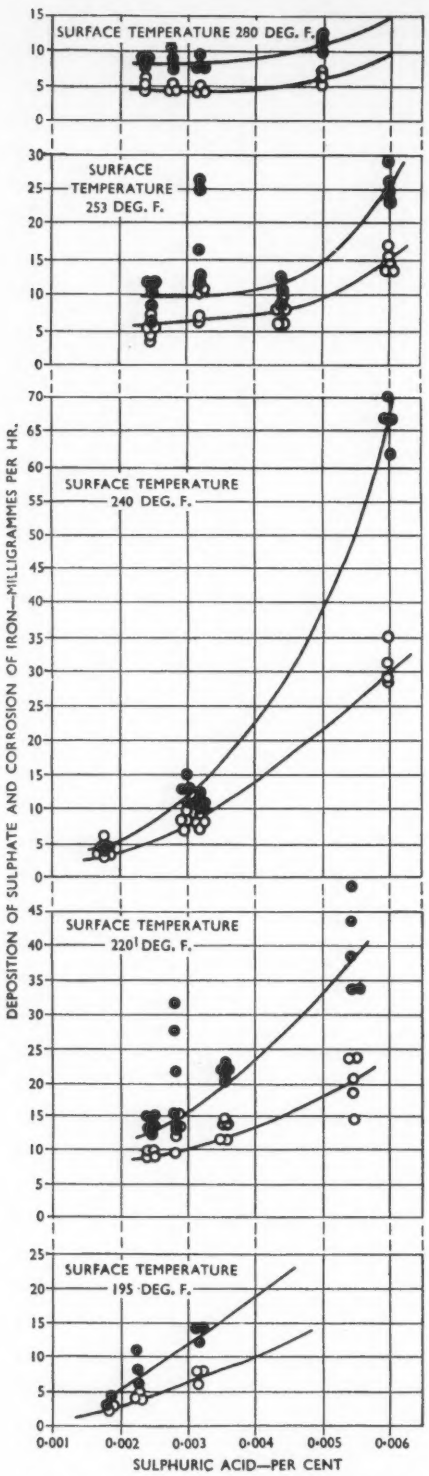


Figure 4—Variation of acid deposition and iron corrosion with acid concentration in flue gas. ●—Sulfate. ○—Iron.

ties inherent in corrosion studies. The values on the mean curves drawn through these points have been replotted in Figure 5 on co-ordinates of surface temperature and (*a*) iron corrosion or (*b*) sulfate deposition

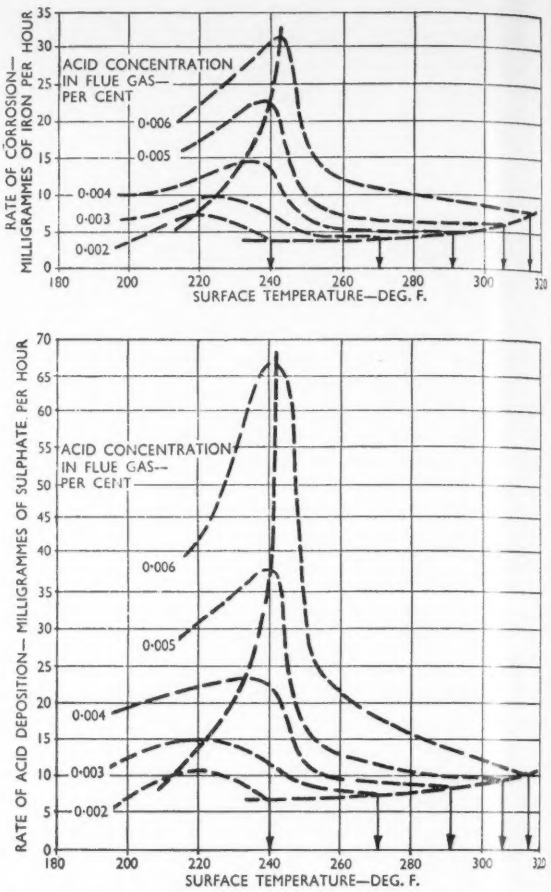


Figure 5—Variation of corrosion and condensation with surface temperature for various acid concentrations in flue gas. Arrows denote the dew-point temperatures given by the various acid concentrations.

for various concentrations of acid in the flue gas. It will be noticed that these results show both corrosion and acid deposition occurring under conditions where the dew-point is below the surface temperature. Some of this 'residual' corrosion can probably be attributed to the experimental technique employed; further tests did, indeed, indicate that some corrosion was taking place during the initial warming-up period. This could be caused either by the action of slight traces of sulfur trioxide arising from sulfur compounds in the coal gas or by the distillation of sulfur trioxide from sulfatic deposits previously formed in the ducting. It is known, however, that slight corrosion can occur on surfaces at temperatures above the dew-point.

Discussion

It may be seen from Figures 3 and 5 that:

1) Both the rate of acid deposition and the rate of corrosion increase to a maximum value as the surface temperature falls below the dew-point. The resulting curves are similar in shape to those relating electrical conductivity to surface temperature as measured with the dew-point meter.

2) These peak rates occur at surface temperatures within the range 215-245 F, depending on the dew-

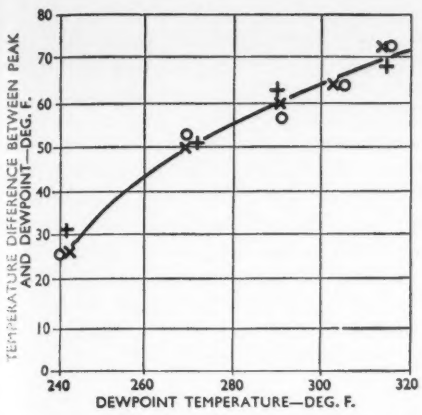


Figure 6—Relation between the position of the peaks and the dew-point. + —Dew-point readings. ×—From sulfate readings. ○—From iron readings.

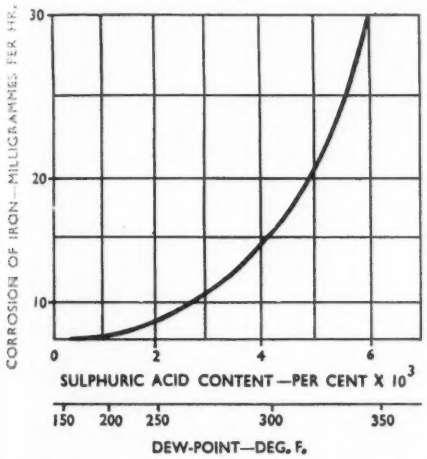


Figure 7—Variation in rate of increase of conductivity and corrosion with acid concentration. Surface temperature 240 F.

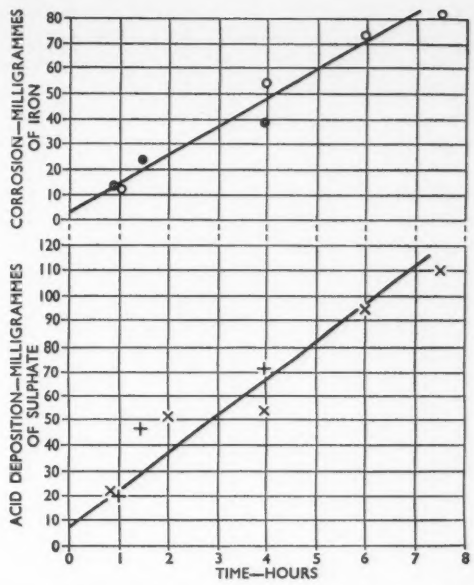
TABLE 3—The Variation of Sulfate/Iron Ratio with Acid Concentration and Surface Temperature

Sulfuric Acid Content of Flue Gases, Percentage by Volume.	Surface Temperature, Degrees F.					
	200	220	240	260	280	300
0.006	....	1.85	2.05	1.75	1.6	1.5
0.005	....	1.80	1.65	1.85	1.75	1.7
0.004	1.9	1.85	1.7	2.0	1.8	....
0.003	1.8	1.6	1.7	1.8	....	....
0.002	1.75	1.6	1.75	....	....	....

point temperature. The relation between the position of the peaks and the dew-point temperature is shown in Figure 6.

3) Variations in the ratio between the rate of acid deposition (as sulfate) and the rate of corrosion (as iron) are not large. Values of this ratio, taken from Figure 5, are given in Table 3. It will be seen that these are all within ±15 percent of the value of 1.72—equivalent to all the acid being converted to ferrous sulfate.

4) At any given surface temperature there is a rapid increase in the corrosion with increasing quantity of acid in the gases. The magnitude of this effect at a surface temperature of 240 F is shown in Figure 7, a subsidiary scale shows the equivalent dew-points.



Test 1	Sulfuric Acid in Flue Gases, Percent	Plate Temperature, Deg. F.	Sulfate	Iron
1	0.0038	236	+	•
2	0.0040	256	×	○

Figure 8—Variation of corrosion and acid deposition with time.

This curve indicates that a reduction in a high dew-point is likely to reduce corrosion to a far greater extent than a similar reduction at a lower dew-point.

A comparison carried out between the experimental determinations of the rate of increase of conductivity as measured by the dew-point meter and the rate of increase of corrosion showed that, while the relation between these two terms is linear at a constant surface temperature, there appears to be a significant change in the proportionality factor with varying surface temperature.

The conditions are so different between these tests and those recently carried out by Flint and Kear, described under Introduction, that detailed comparison is probably not justified. Calculations have shown, however, that the rate of corrosion per unit area of metal surface is, under similar conditions, of the same order as that which they obtained, using hemispherical metal caps. The sulfate/iron ratios in the present series of tests are, however, only about one-third of those that they obtained, and a possible explanation is that on a rotary air-heater some of the acid deposited from the hot flue gas evaporates off as the rotor passes through the air stream. The rotor speed on the model in the present tests was faster than that now generally employed in practice but, although an investigation into the effect of rotor speed lies outside the scope of these tests, it is thought unlikely that this would to any large extent affect the corrosion.

Comparison with full-scale conditions is also difficult, especially as it is to be expected that the rates of acid deposition and corrosion obtained during

1-hour intervals will be greater than those measured over longer periods when the build-up of a protective layer, consisting of the corrosion products together with dust deposited from the flue gases, will reduce the rates of reaction. A few tests over periods of up to 8 hours were carried out in an endeavor to investigate this effect, and some of the results are shown in Figure 8. These results, though not very conclusive, indicate that the rates of corrosion and sulfate deposition are fairly constant over periods of this length.

The greatest difference between these tests and the conditions experienced in actual operation, however, is that, although the general flow and temperature conditions simulate full-scale practice, the dust burden of the gases was very low. All flue gases, however, contain dust and fly-ash particles in varying concentrations and size and of different constituency, depending on the fuel and firing appliance. The possible effects of this dust have been discussed in an earlier paper (Thurlow 1952) in relation to the use of an air-cooled metal probe for studying the corrosive nature of boiler gases, and it is hoped to extend this present series of tests to include a study of this variable.

Acknowledgments

The author wishes to thank Dr. G. Whittingham and other colleagues at BCURA for their help and advice.

The work described in this paper forms part of a research program undertaken by the British Coal Utilisation Research Association for the Boiler Availability Committee and is published by permission of that body and the Director General of BCURA.

APPENDIX

References

Corbett, P. F., and Flint, D. 1953 *Jl. Inst. Fuel*, **25**, p. 410.
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Flint, D., and Kear, R. W. 1951 *Jl. Applied Chem.*, **1**, p. 388.
Kear, R. W. 1951 *Jl. Applied Chem.*, **1**, p. 393.
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Communications

Mr. U. Blomquist (Vasteras, Sweden) wrote that the Steam Power Department of the Swedish State Power Board had carried out some work on corrosion and deposition problems in connection with air preheaters. The work referred partly to oil firing and partly to combined oil and pulverized-coal firing.

In regard to oil firing they had confirmed the work carried out earlier by BCURA. They had noticed that in the burning of residual fuel oil, a small content of coke and soot in the combustion gases influenced the circumstances remarkably. In tests with a laboratory refractory furnace and a large steam boiler of 660,000 lb. per hr. the rate of condensation had been remarkably higher in the test furnace than in the boiler at the same dew-point. In both cases the combustion had been very satisfactory.

The deposits built up with oil-firing had often shown a hydroscopic effect. It was very difficult to make an exact measurement of that effect with an ordinary dew-point meter. Sometimes, however, the condensation had started by decreasing the surface temperature 20 C above the dew-point, and the change in conductivity had been very distinct. By running with the temperature in reverse direction, the condensate had left the surface at a still higher temperature. Therefore, in an ordinary steam boiler with oil firing it could happen that the corrosive acid condensate, built up during the start of the boiler, did not leave the deposited preheater surface, in spite of the fact that the actual surface temperature during operation was well above the dew-point.

The decrease of the dew-point due to addition of pulverized coal would usually be quite small. On the other hand, however, a remarkable decrease of condensate built up below the dew-point had been noticed, and that would considerably minimize the risk of corrosion. In some cases they had not noticed any condensation. The fly ash from the pulverized coal kept the air preheater surface quite clean, and no hygroscopic effects had been observed. The necessary addition of pulverized coal to obtain that improvement was quite small, not exceeding 10 percent.

A small addition of pulverized coal in oil firing might be a good solution of the corrosion and deposition problems, which often really were very serious with oil firing. That was particularly useful in Sweden, where many of the larger steam boilers were provided with equipment for burning both oil and pulverized coal, because of the special fuel situation.

Mr. J. H. G. Carlile (London) wrote that each new contribution involving the use of the BCURA dew-point meter in studies of acid condensation and corrosion threw further light on the complex problems involved and helped to define more exactly the significance of dew-point measurements. It was clear, however, that there were still considerable difficulties in the application of such techniques to conditions prevailing in boiler plant, where, as pointed out by the author, the flue gases contained substantial amounts of dust.

The present investigation had given some interesting results, and the type of equipment used should be of considerable value in further studies of the corrosion of metals exposed to boiler flue gases. The ready removal of test pieces gave that method of experiment considerable advantage over methods using test probes; it would, for example, be suitable for comparing under identical conditions the corrosion-resistant properties of different metals and alloys. In that connection, it was of interest to note that a regenerative preheater had been employed in a recent investigation of the rates of corrosion of different materials under normal operating conditions (U. S. Bureau of Mines (1953).[3]

As in earlier investigations, peaks had been found in curves relating surface temperature with rate of increase in conductivity measured by the dew-point meter, and with rates of corrosion and acid deposition on a metal surface, but the present peaks occurred over a more closely-defined temperature range. Corbett, Flint, and Littlejohn (1953) had found a peak in the rate of increase in conductivity at about 50-70 F below the dew-point. Taylor (1951)[4]

(3) United States Bureau of Mines 1953 Report of Investigation No. 4996.
(4) Taylor, H. D. 1951 *Trans. Faraday Soc.*, Vol. 47, p. 1114.

had found a maximum rate of condensation of acid at a surface temperature of the order of 90 F below the dew-point. Flint and Kear (1951) had found that for a given dew-point, peak values in acid deposition and corrosion occurred at a surface temperature of between 35 and 80 F below the dew-point, a result which had found confirmation in later work by the author (1952). It was of interest that peaks in the present tests had not been specifically related to the actual dew-point temperature, and occurred in the temperature range 215-245 F, regardless of the amount of acid present in the gases. That observation supported the view put forward by Rylands and Jenkinson (1948),[5] who had suggested that the peak rate of attack by sulfuric acid on steel corresponded with a range of metal surface temperature from 215 to 250 F. It had been shown by Taylor (1951) that the strength of acid condensing on a surface was a function of surface temperature; it was not surprising, therefore, in view of the dependence of rate of corrosion on acid strength that maximum corrosion occurred over a closely-defined temperature range, the actual dew-point of the gases influencing the rate of condensation of acid rather than its strength. The fact that the mean lines in Figures 3 and 5, relating the maxima with surface temperature, were tending to be asymptotic to the vertical axes, suggested that with even higher concentrations of acid in flue gases the maximum corrosion would occur over the same temperature range.

An important conclusion from the present study was that at any given surface temperature there was a rapid increase in corrosion with increasing quantity of acid in the gases. Furthermore, as shown in Figure 7, with gases of high dew-point, a small increase in dew-point caused a marked increase in the rate of corrosion. That had an important bearing on the question of the increased troubles likely to be experienced if there were further increases in the sulfur content of certain classes of fuel where the sulfur content was already high. Because it had been found that such increases in sulfur content had very little effect on the dew-point temperature, there had been a tendency in some circles to suggest that there would therefore be little risk of increased corrosion. The present finding should sound a necessary note of warning against such unjustified assumptions.

Mr. H. M. L. Coward *(Associate Member)* wrote that the interesting paper did confirm that the acid dew-point and sulfur trioxide relation still obtained in regard to corrosion when a steel plate passed alternatively through air and acid-bearing gas. The author had rightly pointed out the difficulties of testing on full-scale industrial installations, but it could be suggested that each full-scale industrial installation did pose its own problem though many variables were common to all installations.

With modern stoker-fired units the gas temperature gradient through a contra-flow heater could have a value 460-290 F and the air temperature gradient would be in the region of 80-280 F for such a design. With those operating temperatures the steel elements would have a temperature in the region of 180 F at the 'cold' end and 375 F at the 'hot' end. From a reading of the various curves, Figures 3-5, it could be assumed that, for an air heater designed for terminal conditions as set out above, maximum corrosion of elements would take place in a zone approximately one-quarter the distance between the cold and hot ends of the elements, if corrosion were uninfluenced by any other variable. With industrial installations the severe corrosion zone was, within his own experience, always very near to the 'cold' end edge of the elements, usually within an inch or so. It could be suggested that, non-streamline gas and air flow which was inevitable with rotating elements, resulted in protection of the extreme 'cold' end tip, while tests which had been taken in power stations under his own control did show that soot-blowing (superheated steam) did affect the corrosion problem by displacing the corrosive material an inch or so away from the 'cold' end. The position of the zone of severe corrosion was of extreme importance, for perforation of the element resulted ultimately in the displacement and loss of sections of element which were themselves only slightly reduced in thickness except at the perforation.

Also, the curves in Figures 3-5 would tend to show that, for a given acid concentration in the gas, the effect of variation in metal temperature on corrosion was a straight-line function so far as displacement of the maximum corrosion zone was concerned. A very useful line of experiment would be a check on corrosion when varying the inlet-air temperature, say, between 50 and 150 F, with control of humidity; the gas temperature being maintained constant.

Mr. H. Karlsson *(Member)* wrote that the author, within limitations imposed by laboratory facilities, had attempted to relate field and laboratory conditions to a common base.

The initial experiment with clean gas, free from dust, had been proposed as the best approach in a series of tests to find cause and effect of problems relating to heat recovery equipment in the flue gas cycle. That that had been done with a model regenerative air-preheater was a progressive step, in that investigations were more thorough and complete than with a recuperative type of unit, owing to greater accessibility.

In time, the sulfate-deposition/iron-corrosion ratio might be an important development in predicting availability.

A statement made by the author and frequently repeated, referred to the probability of acid on the heating elements of a regenerative heat exchanger being evaporated as the rotor passed through the air stream. That phenomenon, it appeared, could be within the limits of the author's next series of tests with dust-laden gases. Perhaps the addition of a second thermocouple, located diametrically opposite the first one, would be helpful in that determination. It was suggested that such test would cover the range maintaining a fixed surface-temperature with varying gas- and air-inlet temperatures to determine

(5) Rylands, J. R., and Jenkinson, J. R. 1948 *Proc. I. Mech. E.*, Vol. 158, p. 405.

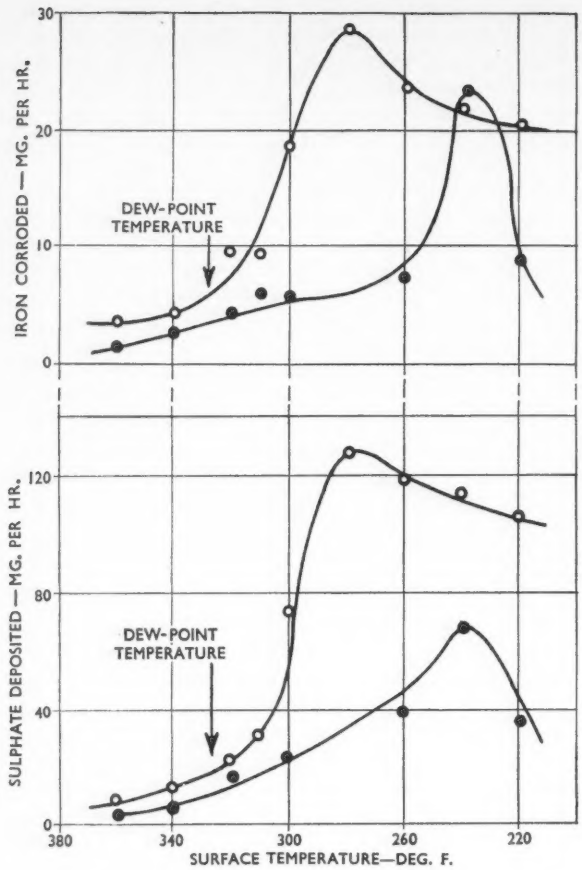

Figure 9—Effect of auxiliary pulverized-fuel firing. O—Pulverized fuel off. O—Pulverized fuel on.

whether a drying effect existetd by the air stream, and if such effect perhaps reached an optimum value beyond which it might be detrimental. He had in mind particularly a point where very low air-inlet temperatures must be dealt with as for outdoor plants which were common in the United States.

Author's Reply

Mr. G. G. Thurlow, in reply to the communications, wrote that it was very gratifying to hear from Mr. Blomquist that work in Sweden had confirmed the conclusions reached at the BCURA concerning the influence of smokes and dusts on the rate of acid attack on air heater plates and that it had been possible to use that work in alleviating troubles in oil-fired units. The observation that the addition of pulverized-fuel-firing (to increase the dust burden) brought about a marked reduction in corrosion, although having only a slight effect on the dew-point temperature, agreed with his own observations. Figure 9, for example, showed results obtained on a stoker-fired boiler fitted with auxiliary pulverized-fuel-firing (Corbett and Flint 1953) using the corrosion probe referred to in the paper (Thurlow 1952). From short-term trials, it appeared that the presence of dusts of that type did not inhibit the formation of sulfur-trioxide but retarded its condensation as sulfuric acid and subsequent corrosion on the metal surface, probably by a mechanism of physical absorption. It should be mentioned, however, that it had been found (Littlejohn 1952)[6] that some smokes such as zinc oxide reacted chemically with the acid.

The influence of that dust must be, as had been pointed out in the paper, the major problem in relating the results on the model to actual practice, and probably explained most of the discrepancies between the temperature at which the maximum corrosion occurred in laboratory and semi-scale work and in industrial practice, mentioned by Mr. Coward; although he had himself seen a rotary air-heater in which the bulk of the corrosion had occurred 1-2 feet from the cold end. Furthermore, Karlsson and Hammond (1953)[7] had pointed out that field investigations had proved that the actual cold-end metal temperatures could be appreciably lower than estimated by taking the mean of the gas and air side temperatures, and it might be that the corrosion on the 'cold' edge referred to by Mr. Coward was due to the temperature approaching the 'water' dew-point.

The location of the zone of maximum corrosion was influenced in practice by a variety of secondary features. Mr. Blomquist had mentioned one very important such point: that once deposition and corrosion commenced—for example, during starting up—they tended to persist, even though subsequent conditions were unfavorable to further condensation. The flow of acid and, particularly, acid-laden dust might also transfer the point of attack from the region of condensation to other zones, generally further through the boiler.

Mr. Carlile's contribution summarizing the various experimental values for the temperature band over which the peak rate of corrosion occurred was extremely useful. It was evident that while it was possible to state from available information that the peak occurred within a temperature band of, roughly, 210-270 F, more knowledge was needed of the influence of factors such as the water content of the flue gas and the nature and quantities of flue dust. Basic information of that kind would be of great value in relation to the safe minimum metal temperatures which could be employed for different methods of firing and for different fuels without risk of corrosion.

Further tests, as outlined by Mr. Coward and Mr. Karlsson, would undoubtedly be of interest. Mr. Coward had suggested, in effect, studying the influence of the temperature differential between gas and plate. Though the indications were that that was small, the conditions were of interest in assessing the value of air and flue-gas recirculation. The contribution by Mr. Karlsson, who had had a large part in the execution of the work by the U. S. Bureau of Mines referred to by Mr. Carlile, was most welcome. The evaporation of acid from the heating elements of a rotary air-heater on the air side was an unknown quantity. The inference from the present work was that while the evaporation did not reduce the corrosion greatly, it could result in appreciable acid passing into the cold air ducting where it might cause corrosion.

(6) Littlejohn, R. F. 1952 *Jl. Applied Chem.*, Vol. 2, p. 289.
(7) Karlsson, H., and Hammond, W. E. 1953 *Trans. Amer. Soc. Mech. Eng.*, Vol. 75, p. 711.

Discussions

Proposed Standard Laboratory Procedure for Screening Corrosion Inhibitors for Use in Oil and Gas Wells. Publication 55-2. *Corrosion*, Vol. 11, No. 3, 143t-146t (1955) Mar.

Questions by A. H. Roebuck, Continental Oil Co., Ponca City, Okla.:

Approximately how many compounds have been tested by this method? Does this number cover the various structures and formulations now generally known and used as inhibitors? These questions are not intended to discourage the acceptance of this test. The committee certainly is to be congratulated on its work. More work of a similar nature is needed on other corrosive environments.

Reply by J. S. Spalding, Jr.:

About 12 inhibitors covering the range of commonly used amine (polar type) inhibitors have been reported on. Tests have been run on about 50 by various persons but not fully reported to T-1K.

Question by John R. Gilcrease, Texas Eastern Transmission Corp., Shreveport, La.:

Did you standardize on the type of metal test strips before running tests in different laboratories?

Reply by J. C. Spalding, Jr.:

No, we specified a mild, cold rolled steel. Sun Oil Co. uses 1020.

Discussion by R. S. Treseder, Shell Development Co., Emeryville, Cal.:

Do you feel that the use of room temperature for the test instead of a more elevated temperature, comparable to well temperature, allows more inhibitors to pass, which would not work in practice due to a temperature effect? In our experience some inhibitors lose their effectiveness to a marked degree at elevated temperatures (180-200 F).

Reply by J. S. Spalding, Jr.:

Current opinion is not in agreement with the effect noted above. Elevation of temperature presents mechanical problems that are expensive to overcome. Original work intended only to get the work started. Elevated temperatures may be the first necessary refinement.

Discussion by Loyd W. Jones, Tulsa, Okla.:

Stanolind Oil and Gas Co. has tested a very large number of materials covering a wide range of composition using the recommended procedure. Nitrogen-containing compounds of cyclic, heterocyclic and straight chain structure, both water and oil soluble have been tested. Sulfur and phosphorus compounds and aldehydes have been studied by the method.

Question by Russell F. Stedman, DesPlaines, Ill.:

What attempt has been made—if any—to standardize cleaning of the exposed test piece to determine weight loss?

Reply by J. C. Spalding, Jr.:

Cleaning methods used in this test resulted in negligible weight loss on coupon.

Discussion by Jerome Green, National Aluminate Corp., Chicago:

Mr. Spalding, Mr. Greco and members of the committee are to be commended and thanked for the diligence they have displayed in this work and we have been happy to cooperate with Mr. Spalding in the round-robin testing of the proposed procedure. Our own extensive research on the evaluation of corrosion inhibitors for oil production has made us keenly aware of the difficulties which the committee faces. At the South Central Regional NACE meeting at Houston in October of this year, David B. Boies of our laboratory plans to present our methods and conclusions in some detail.

We wish to mention at this time two factors which can greatly influence the results obtained in the proposed NACE test procedure.

1. If one increases the time of the preliminary immersion of the test coupon in the kerosene from 10 seconds to several minutes, a considerable increase in protection is obtained with some inhibitors. This illustrates the time factor involved in the adsorption of the inhibitor on the metal surface, a factor which may be impotrant in practice.
2. If an "oil soluble" inhibitor is introduced into the brine rather than into the kerosene phase, considerably improved protection may be obtained. The term "oil soluble" or "water soluble" which is often used to describe an inhibitor may not be a satisfactory basis for deciding on the manner of testing. It would seem desirable to test an inhibitor by applying it in both ways to avoid inadvertently rejecting a good material.

These facts are mentioned only to illustrate that as with all other test procedures the proposed NACE method involves a number of conditions which are necessarily arbitrary in nature but which greatly influence the results. In common with many others, our experience has shown that a completely different comparative rating of corrosion inhibitors can be obtained through differences in the test conditions.

In the final analysis the validity of any test procedure must rest on the degree of correlation with field experience. Adequate information on this point seems to be lacking for the proposed test method. It is respectfully suggested that this aspect of the proposed test would be a most appropriate subject for the same thorough study which the committee has made of the test procedure itself.

It is probable that such a study will reveal consid-

erable disagreement among users of corrosions inhibitors as to their relative merit in actual practice. This is to be expected for the simple reason that conditions vary so much with respect to the many variables which can affect corrosion and the inhibitor's performance. No single set of test conditions can be expected to adequately evaluate a corrosion inhibitor for all sour crude production and even for a method designed only for screening purposes great discretion and good judgment must be exercised in its use and in the interpretation of the results obtained with it. It is significant and we think appropriate, that the proposed procedure does not define what constitutes "passing" or "failing" of the test.

Electrical Measurements Applied to Corrosion Investigations by William R. Schneider and David Hendrickson. *Corrosion*, Vol. 10, No. 9, 337-342 (1954) Oct.

The following data are in answer to a question of F. N. Cloninger in connection with the spacing of the connections on a pipe when making current tests by the Hering method.

The distance of four feet between the current and potential lead connections was given since it is a convenient spacing for the average field crew to make and not place the leads too close together. The average excavation is usually three to six feet in length so that instructions to make the connections at the opposite ends of the opening for the Hering test, when we must calibrate the pipe rather accurately, avoids any errors due to a misunderstanding.

In order to determine the condition of the pipe coating on a submarine crossing one or two hundred feet in width by impressing a battery current thereon it is necessary to measure the current on both sides as accurately as possible.

The excessively high potential drop close to the single current connection at the end of a pipe is shown by tests made on several pipes in the tabulation given in Table 1.

Four pipes varying in diameter from 3.3 to 63 inches and of various wall thicknesses were used for a comparative test.

If the current contact is made more than one pipe diameter from the end of the pipe, or on the side of a long line, the excess potential and the length of pipe over which it takes place will be one-half of the values given above.

The fact must be recognized that these conditions exist at BOTH connections to a pipe.

As pointed out by Mr. Cloninger, the percentage of error becomes less as the span of pipe covered by the potential leads is increased, and for all practical purposes can be ignored when making a pipe line survey but when making insulation tests on short spans or testing on lines of unknown dimensions or alloys and unknown resistances due to the high temperatures on exposed lines in the deserts, a Hering calibration is necessary and errors kept at a minimum.

We thank Mr. Cloninger for bringing up the question of the lead spacing since the same question may have been in the minds of many others.

The four foot spacing was used although it gives about four or more times the minimum required in order to avoid excessive amount of supervision of the average help we have on some of the tests.

TABLE 1—Potential Drop Close to Single Current Connection

(1)		(2)		(3)	(4)
Inches	Inches	Dia.	Inches	Millivolts	Millivolts
3.3	.023	1.2	4.0	.325	.34
8.0	.22	.3	.4	.25	.012
20.0	.31	.5	10.0	.296	.006
63.0	.438	....	18.0	0.4	.0012

Effective with this issue discussions to technical articles will appear in the June and December issues only when they do not immediately follow the article to which they pertain. Discussions received from December through May will appear in the June issue and those from June through November in the December issue.

DISCUSSIONS ON TECHNICAL ARTICLES ARE SOLICITED

Discussions on technical articles published in Corrosion will be accepted for review without invitation. Discussions must be constructive, accompanied by full substantiation of fact in the form of tables, graphs or other representative data and be submitted in three typewritten copies.

Authors of discussions are asked to supply one copy of figures suitable for reproduction and will be sent on request a copy of the NACE Outline for the Preparation and Presentation of Papers.

Discussions will be reviewed by the editor of Corrosion and will be sent to the author of the paper discussed for his replies, if any. Publication will be in the Technical Section with full credit to the authors together with replies. Discussions to papers presented at meetings of the association may be submitted in writing at the time of presentation or later by mail to the editorial offices of Corrosion, 1061 M & M Bldg., Houston 2, Texas.

Publication 55-7

Reports to Technical Unit Committee T-1J On Oilfield Structural Plastics*

Part 1. Long-Term Creep of Pipe Extruded From Tenite Butyrate Plastic

By L. W. A. MEYER and R. J. SCOGIN
Tennessee Eastman Company,
Division of Eastman Kodak Company

Abstract

Data are given of creep of extruded Tenite Butyrate pipe under internal pressure. Nine-foot lengths of pipe were maintained under different internal pressures. Data are given in 16 graphs showing individual creep data and four graphs summarizing each of four groups. Tables are given showing safe hoop stress values with corresponding tensile strength data.

THERE is considerable need for data on creep under internal pressure for plastic pipe used in the gas and oil industries and for other structural installations. In an effort to provide the data for pipe extruded from Tenite Butyrate, long-term tests have been undertaken by Tennessee Eastman Company at Kingsport, Tennessee. A preliminary report was issued Oct. 1, 1954. While tests have not been completed the present report serves to bring the information up to date.

A considerable quantity of pipe extruded from Tenite Butyrate plastic has been used successfully in the gas industry for natural gas service lines and in the oil fields for transporting salt water and sour crude oil. Although a few failures have been reported in the oil fields, investigation indicates the possibility that most of these were caused by excessive temperatures and/or pressures. A few are believed to have resulted from contamination of the plastic extrusion material or the pipe not having been extruded under optimum conditions. It is hoped the long-term creep data obtained to date from these continuing tests will prove useful as a guide for the design of service installations to employ as a guide for the design of service installations to employ butyrate pipe, pending completion of the tests and publication of the final results.

Nine-foot lengths of four different sizes of pipe were used in the tests. They were mounted on racks, filled with water and maintained under different internal pressures. Outside diameters of the pipes were measured periodically. Resulting curves show the percentage increase in outside diameter for the different sizes of pipe plotted against time. Internal pressures and hoop stress data (unit fiber stress) also are indicated for each pipe size. The ultimate objective is to determine the highest safe hoop stress which any given size pipe will withstand. The hoop stress is used in calculating the safe working pressure for a given size pipe or for determining the wall thickness necessary to withstand a given pressure.

The information will be presented as follows:

1. Nominal dimensions of the four different sizes of pipe tested.
2. Pipe extruded from two different formulas of Tenite Butyrate, each tested at two different temperatures, presented in four groups.
3. Photographs of the test racks, explanation and discussion of equipment and test procedures.
4. Explanation of the method of calculating the hoop stress values.
5. Sixteen graphs showing creep data on the individual pipes in the four groups.
6. Four graphs summarizing each of the groups.
7. Table showing the safe hoop stress values from these preliminary test data for each group, with corresponding tensile strength data.
8. Graph showing creep of 4.500-inch OD butyrate pipe with 0.250-inch wall during 4½ years of continuous service in an outside installation at 95-105 psi internal water pressure.

Sizes and Formulas of Tenite Butyrate Pipe Tested

Four different sizes of butyrate pipe, wet, were

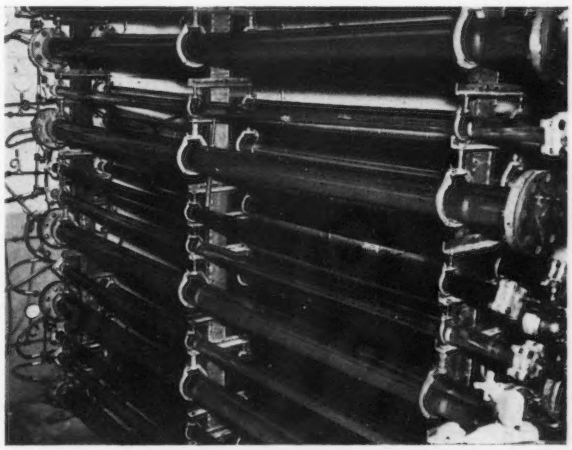

Figure 1—Tenite Butyrate pipe on test rack.

*W. M. Thornton, Atlantic Refining Co., Dallas, chairman; B. W. Bradley, Shell Oil Company, New York, N. Y., vice-chairman. Presented at a meeting of Unit Committee T-1J at Dallas, Texas, October 12, 1954.

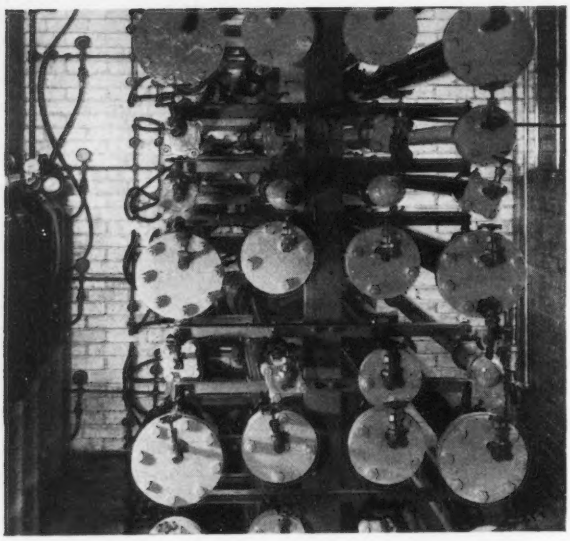

Figure 2—Tenite Butyrate pipe on test rack showing nitrogen cylinders and pressure gauges.

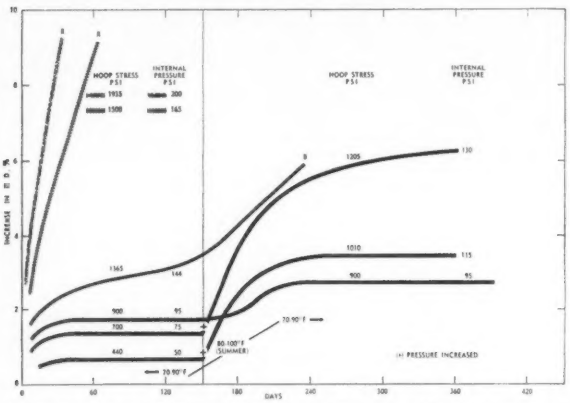

Figure 3—Creep of 2-inch SWP Tenite Butyrate pipe (wet) at room temperature (435E-22300-MH clear).

TABLE 1—Sizes of Tenite Butyrate Pipe Tested

Nominal Size Inches	Types	DIMENSIONS, INCHES		
		OD	ID	Wall
2	SWP	2.250	2.000	0.125
2	IPS	2.375	2.067	0.154
3	IPS	3.500	3.068	0.216
4	*	4.500	4.000	0.250

* OD same as for IPS; Wall .013-inch greater.

TABLE 2—Test Grouping of Tenite Butyrate Pipe

Group	Formula	Test Temp. °F
A	*435E-22300-MH Clear	Room
B	265E-20337-MH Black	Room
C	435E-22300-MH Clear	120
D	265E-20337-MH Black	120

* Formula 460 is now being suggested for extruding clear pipe since it contains an improved ultraviolet inhibitor.

TABLE 3—Seals on Pipe Ends

Nominal Size Inches	Type	Type of Fitting
2	SWP	Tapered plugs with tapered back-up flanges and Garlock gasket.
2	IPS	Compression fittings and Van Stone flange assembly (circular end-plate with Garlock gasket).
3	IPS	Van Stone flange assembly.
4	(See Table 1)	Van Stone flange assembly.

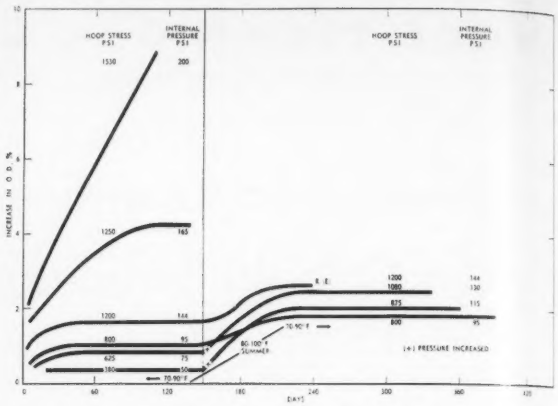

Figure 4—Creep of 2-inch IPS Tenite Butyrate pipe (wet) at room temperature (435E-22300-MH clear).

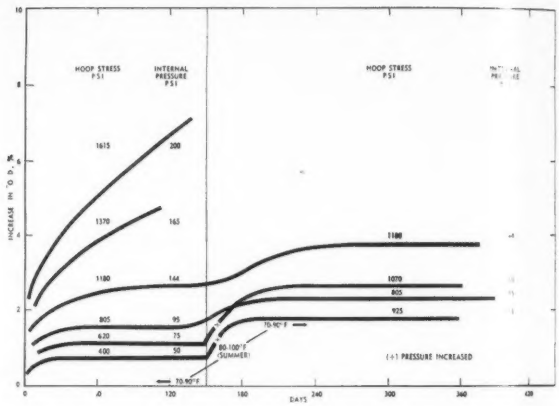

Figure 5—Creep of 3-inch IPS Tenite Butyrate pipe (wet) at room temperature (435E-22300-MH clear).

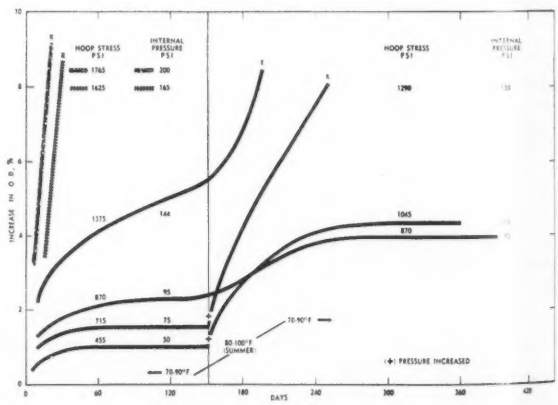

Figure 6—Creep of 4-inch Tenite Butyrate pipe (wet) at room temperature—4.500-inch OD, 0.250-inch wall (435E-22300-MH clear).

evaluated by long-term creep data. These are shown in Table 1 along with the dimensions of each.

Each of the four sizes of pipe was tested, wet, in two different formulas at two different temperatures and at five different pressures. Four test groups, each comprising all four sizes of pipe, were arranged as shown in Table 2.

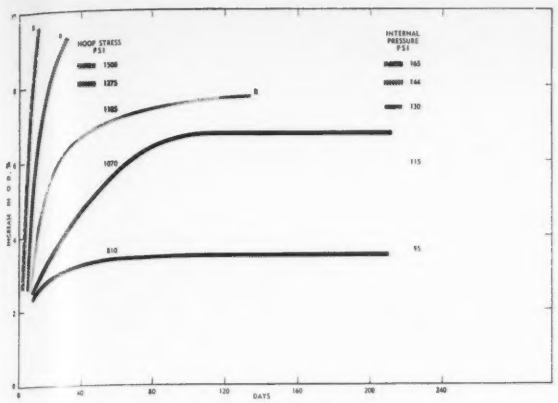

Figure 7—Creep of 2-inch SWP Tenite Butyrate pipe (wet) at room temperature (265E-20337-MH black).

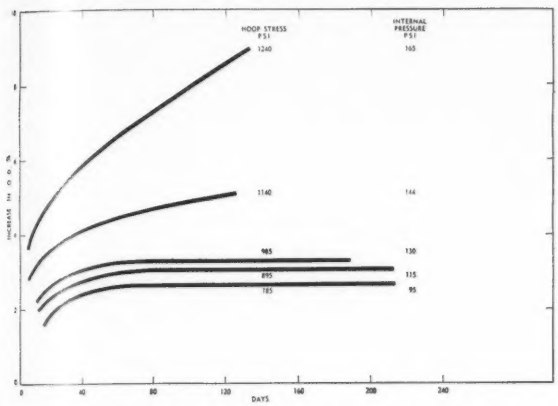

Figure 8—Creep of 2-inch IPS Tenite Butyrate pipe (wet) at room temperature (265E-20337-MH black).

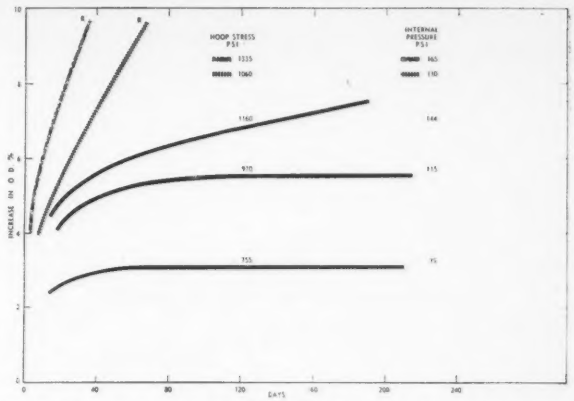

Figure 9—Creep of 3-inch IPS Tenite Butyrate pipe (wet) at room temperature (265E-20337-MH black).

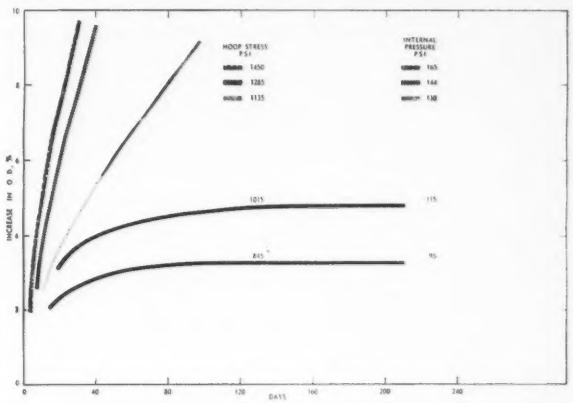

Figure 10—Creep of 4-inch Tenite Butyrate pipe (wet) at room temperature—4.500-inch OD 0.250-inch wall (265E-20337-MH black).

Test Rack, Equipment and Procedure

Photographs of the test racks are shown in Figures 1 and 2.

Test pieces were supported horizontally on standard pipe hangers spaced at about 4-foot intervals. Ends of the pipe were free, i.e., not rigidly held in compression or tension.

Water was held in the pipes by sealing the ends as shown in Table 3.

After pipes were filled with water pressure was applied from cylinders of nitrogen. The pressure was regulated by standard reducing valves. A check valve was installed in each line between the nitrogen cylinder and the water. Ashcroft gauges were used in each system. Needle valves were used between the inlet water line and each pressure system and a control valve was used for each two test pieces. Chart recorders were used to record the temperature.

The test rack for Groups A and B was erected in a room steam heated during the winter with a room temperature variation of about 70-90 F. This range increased to about 80-100 F during the summer months.

The test rack at 120 F for Groups C and D was erected in a room containing a vertical unit steam heater with a fan and Anemostat mounted about 27 inches above the test rack. An inverted V-shaped hood of sheet metal prevented the hot air from making direct contact with the pipes near the top of the rack. The temperature was held at 120 ± 4 F within the test area (from the top to the bottom and end to end of the test rack) by the use of a Foxboro temperature recorder-controller. This instrument operated a diaphragm motor valve in the steam line.

The diameter of each pipe was measured at four different places with a flat steel tape, Starrett No. 510-J, which has a pi scale on the back. The scale is graduated in 64ths but can be estimated to the closest 128th of an inch. In general, the largest dimensions from each of the four measurements were used in calculating the percent increase in outside diameter.

Calculation of Hoop Stress Values

Barlow's formula was used to calculate the hoop stress for each pipe. A sample calculation is shown in Table 4 for 2-inch SWP butyrate pipe, formula 435E-22300-MH clear, tested at 120 F under 90 psi internal pressure.

Actual dimensions for outside diameter and wall thickness, rather than the nominal dimensions were used in the calculations. Slide rule calculations were used because they are within the range of experimental error. Hoop stress values were rounded off to the nearest 5 psi.

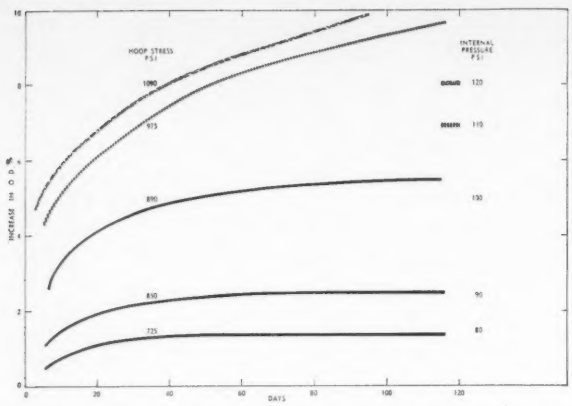

Figure 11—Creep of 2-inch SWP Tenite Butyrate pipe (wet) at 120 F (435E-22300-MH clear).

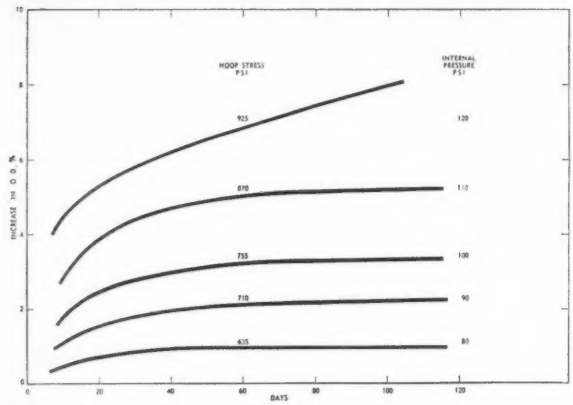

Figure 12—Creep of 2-inch IPS Tenite Butyrate pipe (wet) at 120 F (435E-22300-MH clear).

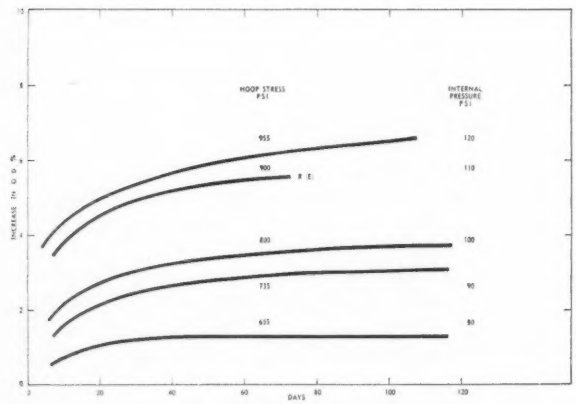

Figure 13—Creep of 3-inch IPS Tenite Butyrate pipe (wet) at 120 F (435E-22300-MH clear).

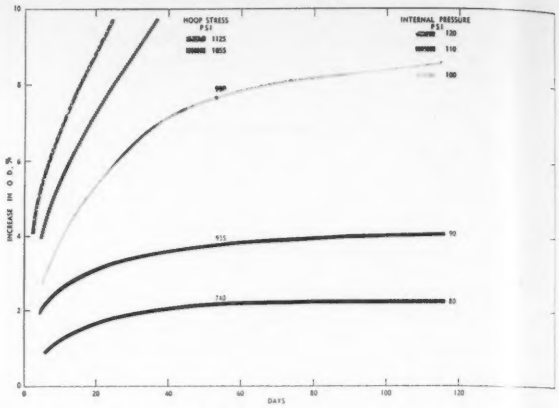

Figure 14—Creep of 4-inch Tenite Butyrate pipe (wet) at 120 F—4.5000-inch OD, 0.250-inch wall (435E-22300-MH clear).

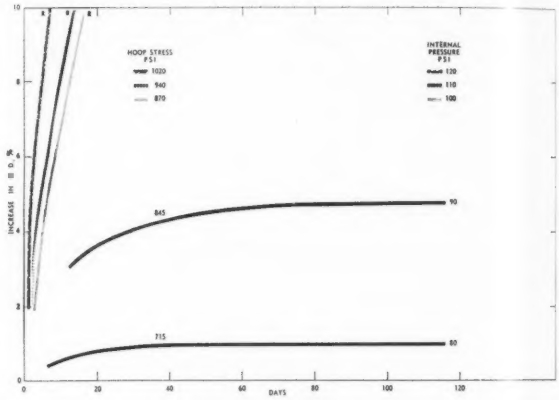

Figure 15—Creep of 2-inch SWP Tenite Butyrate pipe (wet) at 120 F (265E-20337-MH black).

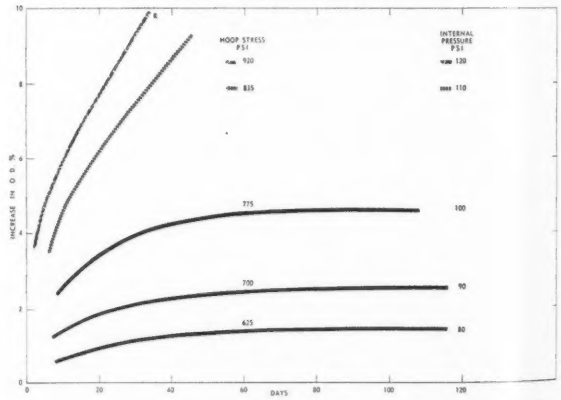

Figure 16—Creep of 2-inch IPS Tenite Butyrate pipe (wet) at 120 F (265E-20337-MH black).

Discussion of Graphs

Percentage increase in OD was plotted against time for each pipe in each group. It is characteristic for butyrate pipe to creep some, even at normal temperatures and at pressures as low as 50 psi. Creep usually continues gradually until the curve approaches a horizontal line. The individual pipe then may be considered as having reached an equilibrium state.

Data presented in Table 5 represent the safe hoop stress values for the four different sizes of pipe in each group.

All test pieces are being continued under test except those identified on the graps as follows:

B = Burst
R = Removed because of excessive swelling
R (E) = Removed in error

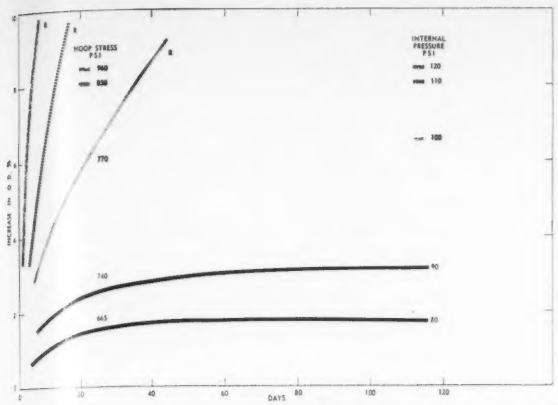

Figure 17—Creep of 3-inch IPS Tenite Butyrate pipe (wet) at 120 F (265E-20337-MH black).

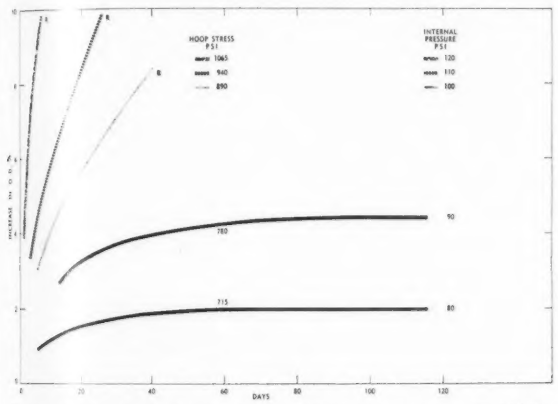

Figure 18—Creep of 4-inch Tenite Butyrate pipe (wet) at 120 F—4.500-inch OD, 0.250-inch wall (265E-20337-MH black).

TABLE 4—Sample Calculation

$$S = \frac{P \times OD}{2 \times T}$$

$$S = \frac{90 \times 2.242}{2 \times 0.119}$$

$$S = 850 \text{ psi}$$

Values

S = Hoop stress psi
P = Internal pressure psi
OD = Outside diameter = 2.242 inch
T = Wall thickness = 0.119 inch

TABLE 5—Summary of Safe Hoop Stress Values From Each Group

Group	Tenite Butyrate Formula	Hoop Stress psi[1]	Test Temp. F	Tensile Strength at Fracture psi[2]
A	435E-22300-MH Clear	1010-1180	Room	4680[3]
B	265E-20337-MH Black	810-1015	Room	4460[3]
C	435E-22300-MH Clear	755-935	120	4020
D	265E-20337-MH Black	740-845	120	4060

[1] Optimum from these tests.
[2] ASTM D638-52T.
[3] At 100 F.
Conditioned by ASTM D618-51T, Procedure A.

Group A

See Table 2 and Figures 3, 4, 5 and 6.

This group represents the first tests conducted on Tenite Butyrate pipe under sustained internal water pressure. Five internal pressures arbitrarily chosen were 50, 75, 95, 144 and 200 psi. The room temperature range during most of the test period was 70-90 F. This increased to 80-100 F during the summer months, which accounts for the further increase in OD.

After about 150 days it was decided to discontinue testing at the highest pressure of 200 psi because most of the pipes failed under this pressure. These were replaced with new specimens at 165 psi. The lowest pressures, 50 and 75 psi, was considered to be too low since the curves for the 95 psi system approached a horizontal line. These pressures were increased to 115 and 130 psi respectively, causing further increase in OD of these pipes. The pressures of 95 and 144 psi were not changed.

Highest safe hoop stress for the four different sizes of pipe in these tests varied from 1010 to 1180 psi. The corresponding maximum increase in OD was 2.5 to 4.3 percent, for a total time of 360 days.

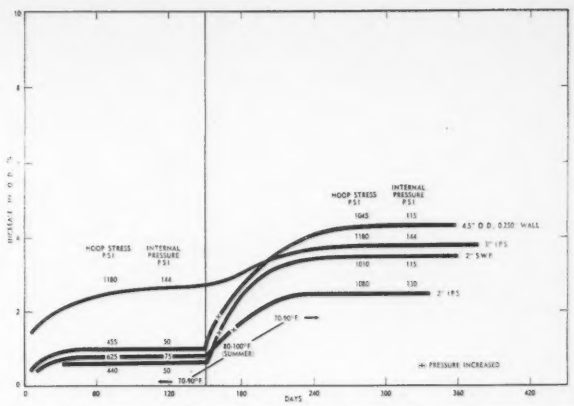

Figure 19—Group A. Summary of creep data on Tenite Butyrate pipe (wet) at room temperature (435E-22300-MH clear).

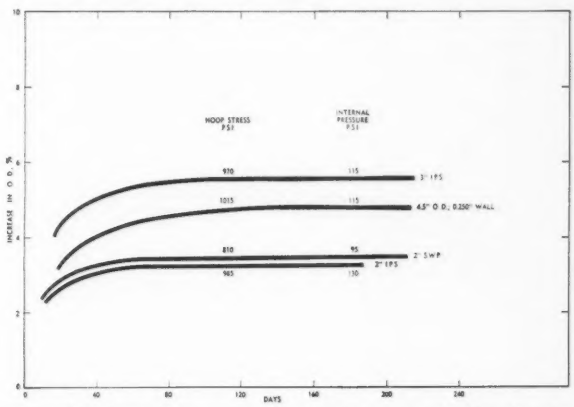

Figure 20—Group B. Summary of creep data on Tenite Butyrate pipe (wet) at room temperature (265E-20337-MH black).

Group B

See Table 2 and Figures 7, 8, 9 and 10.

These pipes were mounted on the same rack as those discussed under Group A. The four different sizes of pipe were tested, wet, at the newly assigned pressures of 95, 115, 130, 144 and 165 psi.

Highest safe hoop stress for the four different sizes of pipe in these tests varied from 810 to 1015 psi.

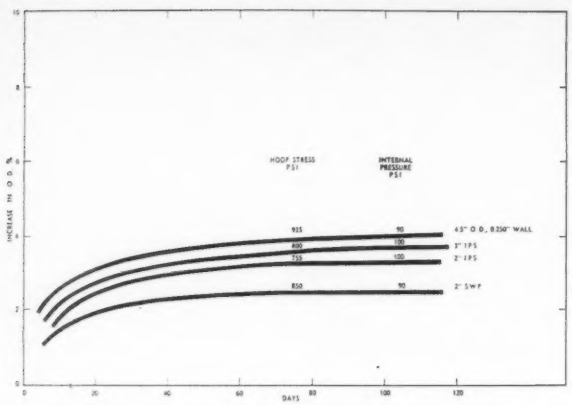

Figure 21—Group C. Summary of creep data on Tenite Butyrate pipe (wet) at 120 F (435E-22300-MH clear).

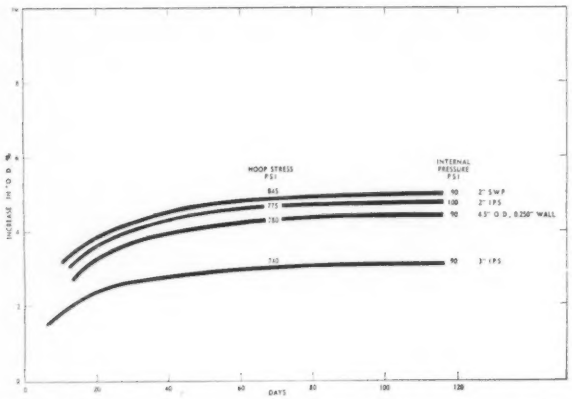

Figure 22—Group D. Summary of creep data on Tenite Butyrate pipe (wet) at 120 F (265E-20337-MH black).

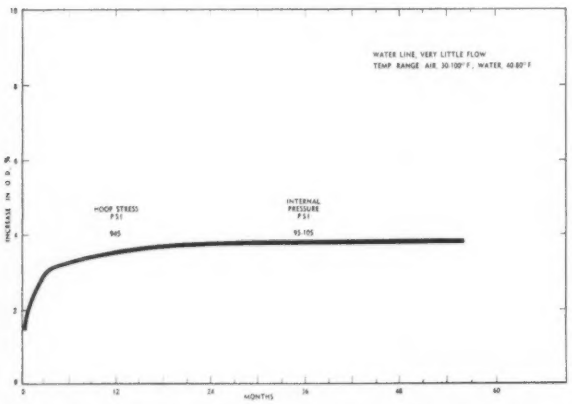

Figure 23—Creep of 4-inch Tenite Butyrate pipe (wet) outside installation—4.500-foot OD, 0.250-inch wall (205E-22300-MH clear).

Corresponding maximum increase in OD was 3.3 to 5.5 percent, for a total time of 210 days.

Group C

See Table 2 and Figures 11, 12, 13 and 14.

Four different sizes of pipe were tested, wet, under five arbitrarily chosen pressures of 80, 90, 100, 110 and 120 psi at a controlled temperature of 120 F.

Highest safe hoop stress for the four different sizes of pipe varied from 755 to 935 psi. Corresponding maximum increase in OD was 2.5 to 4.1 percent for a total of 116 days.

Group D

See Table 2 and Figures 15, 16, 17 and 18.

The pipes in this group were mounted on the same rack as those discussed in Group C. Four different sizes of pipe were tested, wet, under five arbitrarily chosen pressures of 80, 90, 100, 110 and 120 psi.

Highest safe hoop stress for the four different sizes of pipe in these tests varied from 740 to 845 psi. Corresponding maximum increase in OD was 3.1 to 4.8 percent, for a total time of 116 days.

Graphs for Groups A, B, C and D

Figures 19, 20, 21 and 22 represent the highest safe hoop stress values obtained for each size of pipe tested in Group A, B, C and D respectively. The range of values obtained, together with formula, test temperature, and tensile strength are shown in Table 5.

Figures 23 shows creep data on butyrate pipe which has been in service continuously for 4½ years at 95-105 psi internal water pressure. This is an outside installation about 10 feet long, with very little flow. The air temperature range is about 30-100 F and water temperature range is about 40-80 F. The pipe was extruded from formula 205E-22300-MH Clear, with 4.500-inch OD, 0.250-inch wall. The highest hoop stress to which this pipe is subjected is 945 psi. The tensile strength of the material is 5320 psi at 80 F or 4670 psi at 100 F. The OD has increased about 3.8 percent and has been relatively constant since the first 16 to 20 weeks. This indicates that the outside diameter may expand in the range of 3.5 to 4.0 percent, more or less, with continued satisfactory service.

Summary

In planning service installations it is suggested that consideration be given to the safe hoop stress values shown in Table 5. These represent only about 15 to 20 percent of the short time tensile strength.

Previous estimated safe working pressures for pipe extruded from Tenite Butyrate have been calculated on an arbitrarily chosen basis of 20 percent of tensile strength. A considerable quantity of butyrate pipe has been installed on the basis of this guide and, in general, it has proved satisfactory. The data in this report roughly confirm these previous assumptions.

The tests described in this report were run at a constant pressure and were not subjected to impact loading caused by water hammer or by external force.

Future Plans

It is planned to continue these long-term creep tests to obtain the highest safe hoop stress values for various temperatures.

An attempt will be made to correlate the data thus obtained with short-time tests on tensile bars, wet, at the same temperatures as those used for the creep tests.

This report is for information only. The technical advice supplied in it is furnished without charge. Eastman Kodak

Company and Eastman Chemical Products, Inc., which are, respectively, the producer and seller of Tenite Butyrate, must necessarily disclaim responsibility for all results of such advice and of the use of the products, methods and apparatus mentioned herein. It is the user's responsibility to determine suitability for the user's purpose of any products, method or apparatus mentioned in this report and to adopt such precautions as may be advisable for the protection of property and health of persons against any hazards that may be involved in the handling and use thereof. No statement or suggestion in this report is to be considered a recommendation or inducement of any use, manufacture or sale that may infringe any patents now or hereafter in existence.

Part 2. Structural Behavior of Unplasticized Geon Polyvinyl Chloride*

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B. F. Goodrich Chemical Co.

Abstract

Reports of an investigation of the effects of temperature on the physical properties of Geon non-plasticized polyvinyl chloride and the effect of temperature on short term tensile properties are given. The tests show that at relatively low stresses the deflection and rate of creep are directly proportional to applied stress. Above some stress limit varying between 2200 and 3000 psi deflection and rate of creep increase very much faster than stress. A minimum safety factor of 5 to 1 or 20 percent of ultimate tensile strength should be used.

DURING the past several years since the announcement of Geon rigid polyvinyl chloride materials a wide variety of applications have been found for them. Of these, numerous structural applications have taken advantage of the excellent physical characteristics and toughness of Geon rigid vinyl compounds.

Present day industry, home and transportation structural applications depend upon extensive testing to insure proper product usage. Design and product engineers for these fields need many properties to aid them in filling this requirement. In addition to short term physical tests, which are widely used in designing products for engineering applications, the effect of temperature on physical properties and long term creep tests are necessary.

To aid the engineer in his work, these structural properties of Geon polyvinyl chloride compounds are being investigated. The work is being done in the research laboratories of the B. F. Goodrich Company. This report contains a summary of some of the work which has been completed to date.* It covers the nature of creep in non-plasticized Geon polyvinyl chloride compounds and effect of temperature upon short term tensile properties.

Geon rigid vinyl resins for structural applications are divided into two general groups. The first contains the Geon resins which are used to make normal impact compounds. These include Geon 101 EP, 103 EP and 404. The second group contains the unique new resin, Geon 404 HI, which is used to produce Geon high impact rigid vinyl compounds.

Compounds from both groups are discussed in this paper. Geon plastic compound 8750 represents the normal impact compounds while Geon Plastic 8700 represents the high impact group. General physical properties for each compound are given in Table 1.

* These data are based on tests which are believed to be reliable. They are given for information only, and no responsibility is accepted for operations not under direct control of B. F. Goodrich Chemical Co.

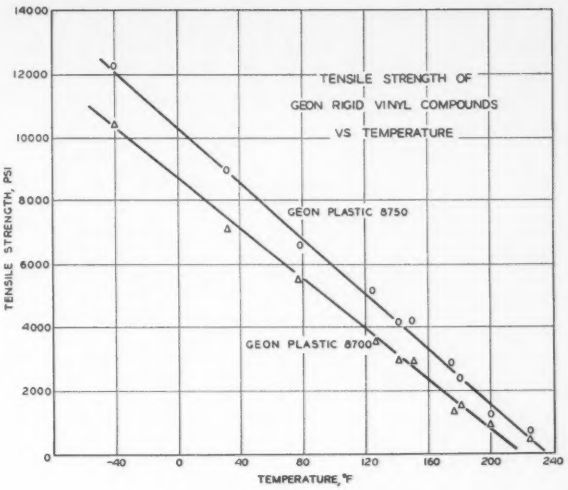


Figure 1

TABLE 1
Physical Properties of Geon Rigid Vinyl Plastics

Property	Geon 8750	Geon 8700	ASTM Test No.
Specific Gravity	1.38	1.35	D 792
Tensile strength, psi @ —40 F	12,200	10,400	D 638
32 F	8,900	7,000	
78 F	6,400	5,500	
140 F	4,100	2,900	
180 F	2,300	1,500	
Compressive Strength, psi	9,600	7,900	D 695
Flexural Strength, psi	13,500	11,000	D 650
Izod Impact, ft. lb./in. notch @ —40 F	0.29	0.9	D 265
32 F	0.44	3.8	
78 F	0.88	17.7	
140 F	4.09	16.4	
180 F	15.90	18.7	
Durometer Hardness "D"	80 ±2	78 ±2	D 785
Deformation under Load, % 24 hr.	0.46	....	D 621
Dielectric Constant:			
60 cps @ 30 °C	3.70	4.01	D 150
1000 cps @ 30 °C	3.62	3.87	D 150
Power Factor:			
60 cps @ 30 °C	1.255	1.93	D 150
1000 cps @ 30 °C	2.82	3.31	D 150
Volume Resistivity @ 95 °C ohms/cm x 10^{12}	1.02	....	....
Dielectric Strength, volts/mil	1413	1085	D 149
Light Transmission	Opaque	Opaque	D 791
Coefficient of Thermal Conductivity Btu/sec/sq. ft./°F/in/10^{-4}	3.5	4.5	....
Specific Heat, cal/°C/gm	0.25	0.25	....
Coefficient of linear expansion per °C x 10^{-5}	5.2	14	D 696
Heat Distortion Temperature °F @ 264 psi	160	150	D 686
Refractive Index N_{25}/D Trans.	1.51	....	D 542

Effect of Temperature on Tensile Strength

Tensile strength is one of the more common properties used in measuring the structural value of materials. Figure 1 shows the tensile strength of Geon Plastic 8750 and 8700 from —40 F to 240 F. Tensile strength plotted on this graph were determined by ASTM test D-638. Tensile samples and testing machine were conditioned at each temperature to achieve equilibrium before samples were pulled. Results of the series of temperature tensile tests on Geon 8750 and 8700 show that the rigid vinyl plastic behaves

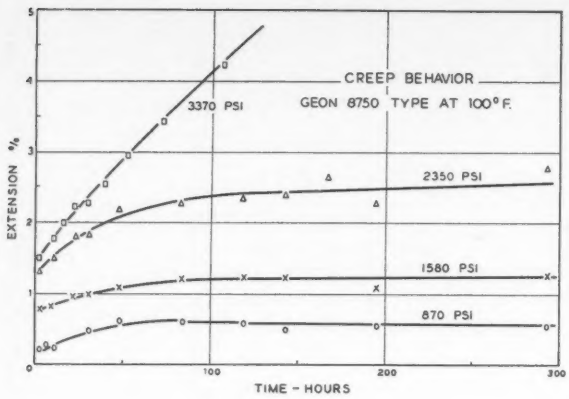


Figure 2

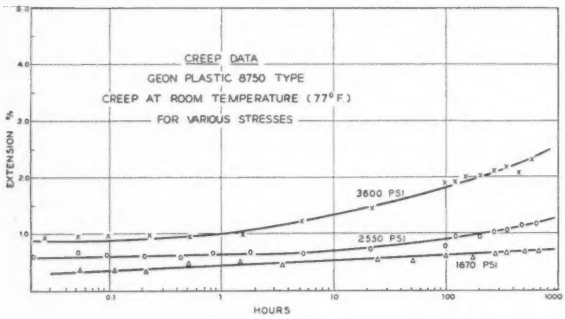


Figure 3

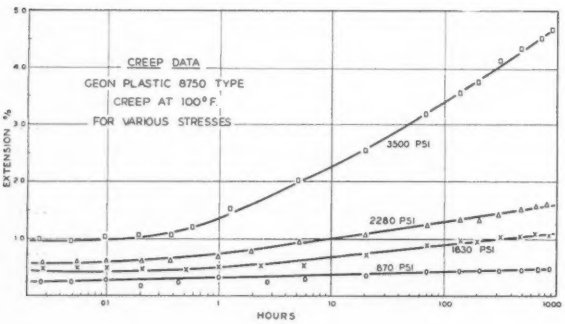


Figure 4

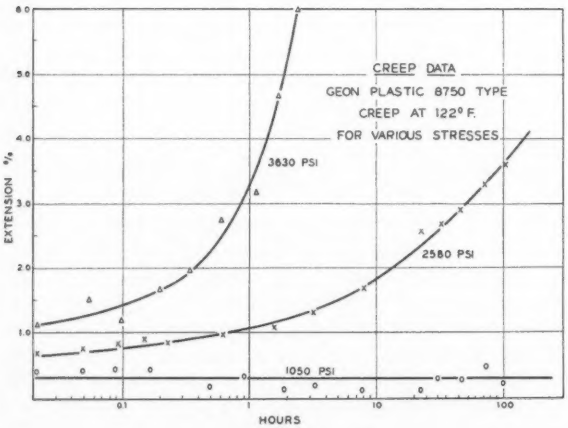


Figure 5

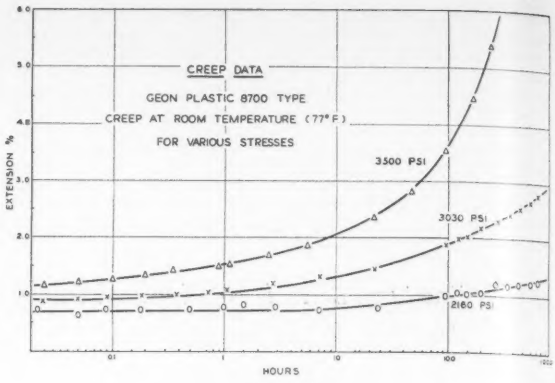


Figure 6

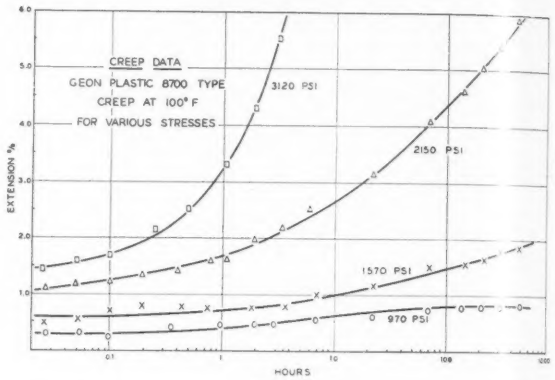


Figure 7

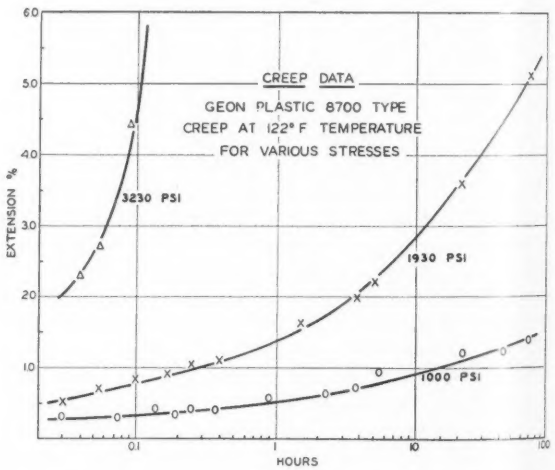


Figure 8

TABLE 2

Young's Modulus (psi)	Geon 8750	Geon 8700
At 77 F	410,000	300,000
At 100 F	360,000	300,000
At 122 F	360,000	230,000

TABLE 3

Am. Std. Pipe—Schedule 40

Nominal Size	1-Inch	2-Inch	4-Inch
Wall Area—sq. in.	0.49	1.06	3.03
Weight per foot	0.30	0.67	1.96
Stress per foot—psi	0.61	0.63	0.65

as metals do. Strength decreases with increase in temperature.

Creep In Rigid Vinyls

The design engineer generally bases his calculations for load bearing structures on yield strength at ordinary temperatures. The yield strength value he uses is less than the ultimate tensile strength. Where service at higher than ordinary temperatures is involved, the designer also must take into account the creep characteristics. That is, the deformation of a load bearing member over a given time period.

The phenomenon of creep is a property encountered in rigid vinyl plastics just as it is in steel. Application of rigid vinyls as load bearing members in structural applications has made it necessary to define the behavior of Geon rigid vinyl plastics under stress at various temperatures over extended time periods in order to serve the purpose of sound design.

Creep information on PVC given in this report was obtained in the B. F. Goodrich Laboratory under static load conditions. Dumbbell samples (1 x ⅛ x .030-inch) were die cut from rigid vinyl sheets. Samples were hung between grips on a frame in the constant temperature room or in a regulated oven. Individual loads were adjusted to given initial stresses from 1000 to 3500 psi. All deflections were measured with a Gaertner slide-micrometer microscope. Index lines spaced about ¾-inch apart were drawn in the reduced section of the dumbbell to avoid errors inherent in jaw slippage.

Creep in rigid polyvinyl chloride was found to be similar to that in steel. Characteristically, the creep curve consists of an elastic extension when the load is first applied, then creep at decreasing rate, a period of essentially constant or minimum creep and a final period of accelerating creep with permanent change of shape.

The length of the sample under fixed load increased in a non-uniform manner as shown in Figure 2. Data shown are for Geon Plastic 8750 type compound. It is typical of all samples tested. Deflection was small initially, but increased at a decreasing rate. To show other features, the data is replotted on a compressed time scale in Figures 3 thru 8. These figures give data for Geon 8700 and 8750 at room temperature or 77 F, 100 F and 122 F for various stresses. The curves show that the initial deflection depends upon the load or stress and further, that deflection increases on the compressed time scale and never levels off to a constant value. Properties of interest in engineering applications can be calculated from these data. These include Young's modulus and creep rate. Initial Young's modulus for Geon 8700 and 8750 are given in Table 2.

Creep rate can be computed for any time or time interval required from the attached curves.

The initial creep behavior does not persist long. M. L. Dannis has described the long time creep behavior by using a term called the time dependent modulus E (t).

$$E(t) = So/s/(t)$$

So = initial stress
S(t) = strain at time, t

In the initial stages of loading E(t) is identical

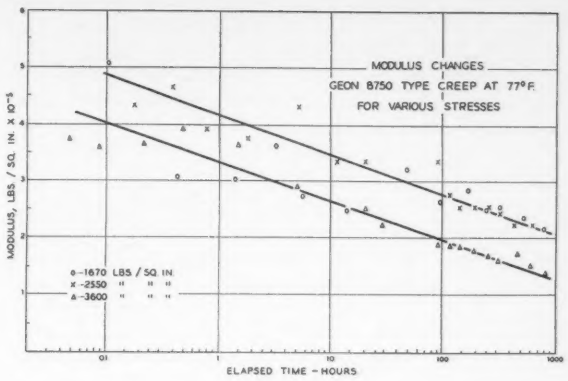

MODULUS CHANGES
GEON 8750 TYPE CREEP AT 77°F
FOR VARIOUS STRESSES
MODULUS, LBS. / SQ. IN. X 10⁻³
o -1670 LBS / SQ IN
x -2550 " " "
Δ -3600 " " "
ELAPSED TIME - HOURS

Figure 9

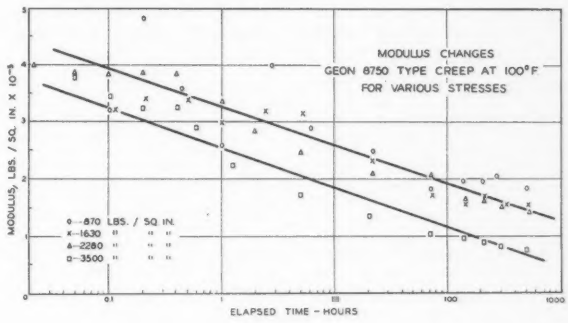

MODULUS CHANGES
GEON 8750 TYPE CREEP AT 100°F
FOR VARIOUS STRESSES
MODULUS, LBS. / SQ. IN. X 10⁻³
o -870 LBS. / SQ. IN.
x -1630 " " "
Δ -2280 " " "
□ -3500 " " "
ELAPSED TIME - HOURS

Figure 10

with the instantaneous modulus. At later time, E(t) includes all the creep that has taken place. Figures 9 through 11 show the time dependent modulus for Geon 8750 at three temperatures for several loadings. At each temperature, the time modulus is independent of the loading up to a certain critical stress value, but decreases with increasing time. At each temperature, the samples subjected to the highest loading have a lower time-dependent modulus and a slightly different slope. Thus, strain is no longer directly proportional to stress. There seems to be a limiting load or stress for these rigid vinyl compounds [(2500 psi) for Geon 8750 and (2200 psi) for Geon 8700] below which the samples behave proportionately to load. Above this limit, both elastic and creep deflections increase faster than expected for small increases of stress. The limiting load is less than the ultimate tensile strength which is 5800 psi for 8700 and 7000 psi for 8750 at room temperature.

Assume that the properties of the rigid vinyl compounds below the limiting stress are the basic properties. It is noted that the time dependent moduli at the various temperatures are similar to each other and may be superposed into one general relationship. Goodrich scientists say this is valid for several reasons up to about 170 F. The assumption is made, based on reliable data that identical processes go on at all temperatures, but the rate increases greatly with temperature.[1] The general relationships, reduced to a time scale at 77 F for Geon 8750 and 8700 is shown in Figures 12 and 13.

Several interesting correlations and extrapolations are evident in Figures 12 and 13. The modulus plot

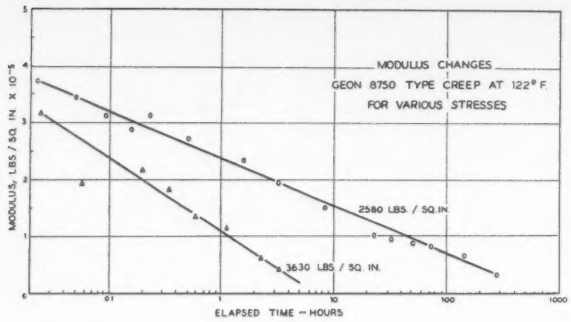

MODULUS CHANGES
GEON 8750 TYPE CREEP AT 122° F.
FOR VARIOUS STRESSES
2580 LBS. / SQ. IN.
3630 LBS. / SQ. IN.
MODULUS, LBS. / SQ. IN. X 10⁻⁵
ELAPSED TIME — HOURS

Figure 11

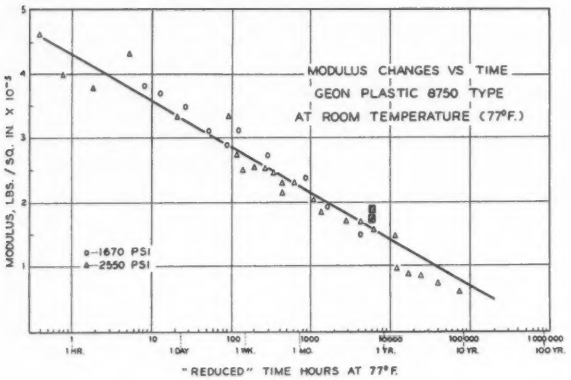

MODULUS CHANGES VS TIME
GEON PLASTIC 8750 TYPE
AT ROOM TEMPERATURE (77°F.)
o—1670 PSI
Δ—2550 PSI
MODULUS, LBS. / SQ. IN. X 10⁻⁵
"REDUCED" TIME HOURS AT 77° F.

Figure 12

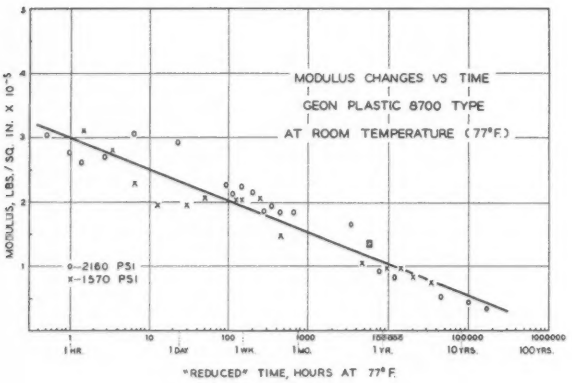

MODULUS CHANGES VS TIME
GEON PLASTIC 8700 TYPE
AT ROOM TEMPERATURE (77°F.)
o—2160 PSI
x—1570 PSI
MODULUS, LBS. / SQ. IN. X 10⁻⁵
"REDUCED" TIME, HOURS AT 77° F.

Figure 13

approaches zero after a very long time period. Zero modulus would mean failure of the material, as far as rigid applications are concerned. This failure would not be by fracture, but by stretching.

On Figures 12 and 13 note two shaded squares plotted beside the modulus curves at approximately 7 months. These are actual points in addition to all points up to 1000 hours which have been obtained to help verify these data. The points are plotted from test data being run at 77 F and under stress indicated on graph. It is believed that future points will follow the curve as closely as the 7-month data. One year data results will be available shortly.

Conclusions

The above work has several practical applications. The design engineer will be able to do his work with confidence if the following is taken into consideration:

1. Geon rigid vinyl compounds based on Geon 101 EP, 103 EP, 404 and 404 HI will creep at rates which depend upon time, temperature stress and compounding.
2. The creep properties of rigid vinyl seem to fall into two general classes of behavior. At relatively low stresses the deflection and rate of creep are directly proportional to the applied stress. Above some stress limit varying between 2200 to 3000 psi deflection and rate of creep increase vary much faster than stress. Therefore, a minimum safety factor of 5 to 1 or 20 percent of the ultimate tensile strength should be used.
3. The creep properties of rigid vinyl compounds are a function of temperature. This means that slightly increasing the temperature greatly increases the creep rate.
4. Rigid vinyl resins creep under load in a manner similar to steel, although the magnitude of creep of the two materials are different.
5. Rigid vinyl compounds fail in tension not by fracture, but by flow or extension to about 100 percent.

This discussion of creep and relaxation has described the behavior of laboratory samples. The design or maintenance engineer can well ask, "How can the data be used properly?" An illustrative problem may be helpful.

Consider a disposal well using a plastic drop pipe, shown in Figure 14. The plastic pipe is hung from the top.

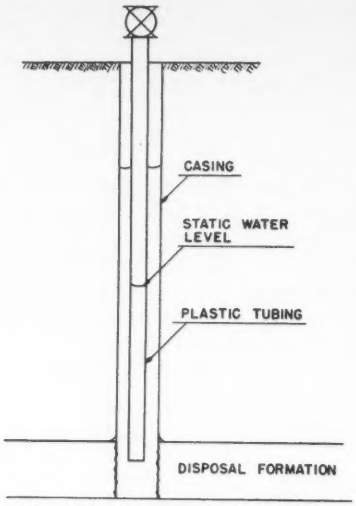


Figure 14—Disposal well plastic tubing application.

TABLE 4

At 2,500 PSI, the maximum "safe" stress

Nominal Size	1-Inch	2-Inch	4-Inch
Free Lengths (ft.)	4,100	3,970	3,860

TABLE 5

Nominal Pipe Size	1-Inch	2-Inch	4-Inch
Pounds/ft.—dry	0.30	0.67	1.96
Pounds/ft—immersed	0.10	0.23	0.66
Stress/foot—immersed	0.21	0.22	0.22
Maximum length at 2000 psi limit	9500	9100	9100

First, assume that all the weight of the pipe is borne by the top piece.

The cross-section area and weight per foot of length are presented in Table 3 for a typical pipe extruded from Geon resins.

Weight of the pipe puts a stress on the cross-section roughly 65 lb. per sq. in. of area per hundred feet of pipe. Choose the maximum allowable safe stress of 2500 lb./sq. in., which allows no safety margin for any errors in computation or defects in pipe or assembly. The length that produces this stress depends slightly upon the size of pipe, as shown in Table 3. These lengths show that self-stressing is not a limit on this use as a drop pipe. In the next discussion, these three lengths are rounded off to an even 4000 feet. The stress at the top will then be 2500 psi.

The expected elastic stretch and creep can be computed as below if the time-dependent modulus is used properly.

$$\Delta L = L \times S_{av.}/E(t)$$

S_{av} is the average stress, since the top sections of the pipe are fully loaded, while the bottom sections are only lightly loaded. Values of E(t) can be picked from the graphs previously shown for the appropriate times. For example, using Geon 8750 at 77 F as shown in Figure 12.

$$E(t) = 4.3 \times 10^5 \text{ psi at 1 hour at 25° C}$$
$$= 1.4 \times 10^5 \text{ at 10,000 hours}$$

Substituting the proper values in the above equation,

$$\Delta L = 4000 \times 2500/2 \div 4.3 \times 10^5$$
$$= 11.6 \text{ ft. (at one hour)}$$
$$\Delta L_2 = 4000 \times 2500/2 \div 1.4 \times 10^5$$
$$= 35.7 \text{ ft. (at 10,000 hours)}$$

Obviously, the creep in one year will be about 34.5 feet. The deflections and creep may seem large to engineers familiar with steel pipe but are normal and reasonable in view of the low modulus (compared to steel).

The question arises, "What about fatigue failure?" Or, "When does the pipe break?" Experiments indicated that no specimen broke until after it had stretched more than about 6 percent, and "necked." Allow 5 percent stretch as the "strain limit." This strain and limiting stress combine to give an "ultimate modulus" 0.5×10^5 psi below which the material will probably fail in tension. This limit represents a stretch of 100 feet for the 4000-foot drop line at a maximum stress value of 1250 psi which provides a safety factor of 2.

Plastic pipe has a density close enough to water that the buoyant effect of the displaced liquid may be important. Typical figures for the same pipe sizes show that the stress is lowered greatly.

The lower effective stress per foot of immersed pipe means that longer lengths can be used. However, laboratory tests have shown a tendency toward notch sensitivity in the presence of water, suggesting that a lower stress limit be used.

Computations similar to those made before would predict 4.1 feet stretch at one hour and 12.6 feet at 10,000 hours for 4000 feet of pipe at 77 F, assuming an average stress of 440 psi (4000 ft. $\times$ 22 lb./ft.) $\div$ 2 and that the presence of water does not change the modulus-time relationship.

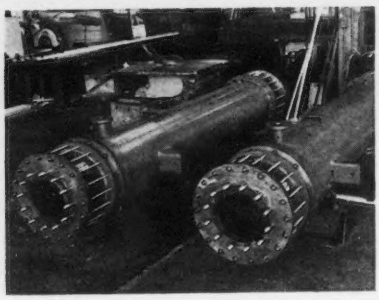
Acknowledgment

Data and information contained in this paper have been abstracted from a report by M. L. Dannis of the Brecksville Research Laboratory of the B. F. Goodrich Company.

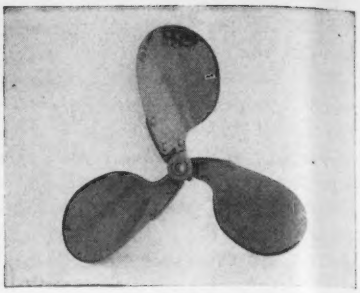
Reference

1. J. D. Ferry, E. R. Fitzgerald, L. D. Grandine, M. L. Williams. *Ind. Eng. Chem.* **44**, 703 (1952).

Pipe Lines



Heat Exchanger



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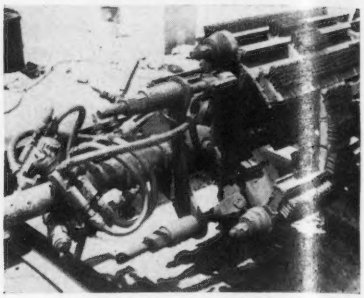

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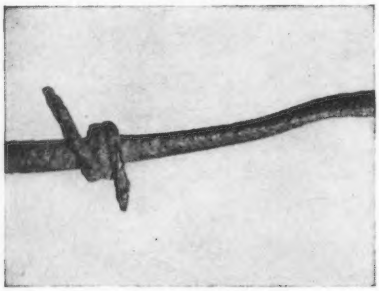

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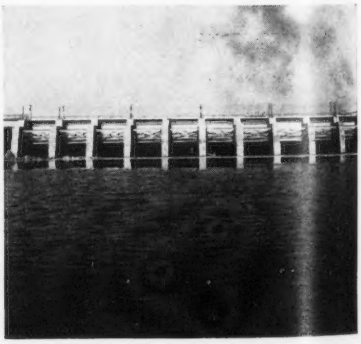

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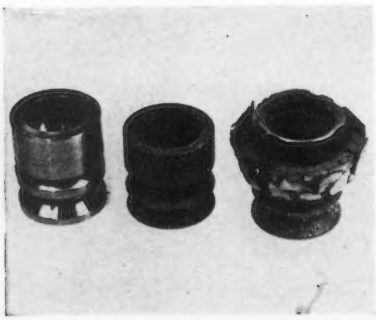

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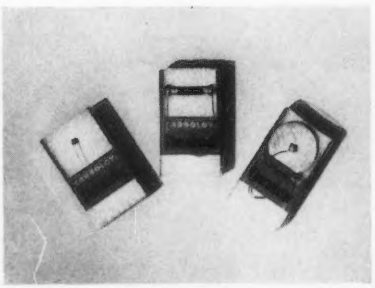
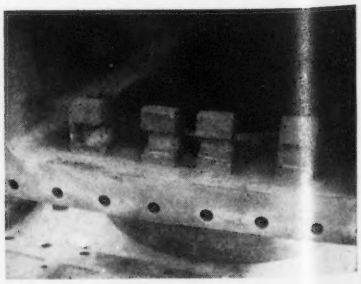




Summary of Data on Use of Structural Plastic Products In Oil Production

*A Status Report of NACE Technical Committee T-1J On Oilfield Structural Plastics**

Abstract

The report covers results of a questionnaire survey to determine experience to date. The most quantitative data developed by the survey were the strapping data on a 250-barrel glass-polyester and a like-size glass-epoxy tank. After two years the glass-polyester tank was still creeping and subject to 0.152 percent volume change due to temperature difference between winter and summer. Not enough data are available on the glass-epoxy tank to determine creep rate, but it was noted that the volume change between winter and summer was about 0.10 percent.

Introduction

UNIT COMMITTEE T-1J on Oil Field Structural Plastics has been in existence two and one-half years. It was organized to investigate the advantages and disadvantages of structural plastics for use in the oil-producing industry. Membership includes representatives of the oil-producing industry, manufacturers of basic plastic raw materials and fabricators of finished structural plastic products. These three concerned groups were included in the hope that close association would serve to expedite development of satisfactory materials for the industry. A further aim of the committee was to amass engineering data which would allow use of presently available materials within their limitations. Such usage would avoid premature failures which damage the reputation of all plastic materials and serve to delay needed development and test work.

Laboratory Studies

T-1J has followed two approaches to the problem. The first of these involved accumulation of laboratory data. Initially, reports of laboratory studies by the various oil producing companies were solicited. Several such reports concerned with various types and formulations of structural plastics were heard. More recently, resin suppliers and fabricators have been urged to present reports of their laboratory tests and findings concerning the structural properties of plastics. Thus far two firms, both chemical companies who manufacture basic resins, have offered usable information concerning the strength of their products.

These reports have done much to provide oil-company engineers with an understanding of plastics. They have established beyond any doubt that the concepts of engineering design normally employed for steel are not adequate for satisfactory application of structural plastics. They have shown that plastics must be considered on their own peculiar merits and cannot be considered a "substitute" for more conventional materials. It is reasonably well recognized that plastics are relatively weak in comparison with most materials of construction. This is true both in regard to tensile and compressive strength, when metals are the basis for comparison. To a lesser extent this is true in regard to compressive strength when compared to cement or concrete. Also, it is realized by most engineers that plastics generally are sensitive to temperature changes. They are brittle at low temperature and seriously weakened at elevated temperatures. Many other properties of plastics, while equally important, until recently have been virtually unknown or ignored by manufacturers and users of structural plastics.

Properties of Thermoplastic Resins

Work reported by A. C. Levinson[1] of Phillips Petroleum Company demonstrates clearly some of the basic performance data of thermoplastics. This work is illustrated by Figure 1 which shows the creep behavior of cellulose acetate butyrate under various constant tensile loads plotted as a function of time. Note that application of tensile load at time zero caused the material to creep. At a stress of 1500 psi and below, this creep continued for several days and then ceased. At a stress of 2000 psi creep was rapid and continuous until failure occurred after several days. In contrast, it is interesting to note that the short-term tensile strength of the acetate butyrate used in this test is in excess of 5000 psi at 80 F.

Similar results, varying only in magnitudes of stress, strain and time were reported for polyethylene, styrene copolymer and vinyl chloride. All were ob-

*W. M. Thornton, Atlantic Refining Co., Dallas, chairman; B. W. Bradley, Shell Oil Co., New York, vice-chairman.

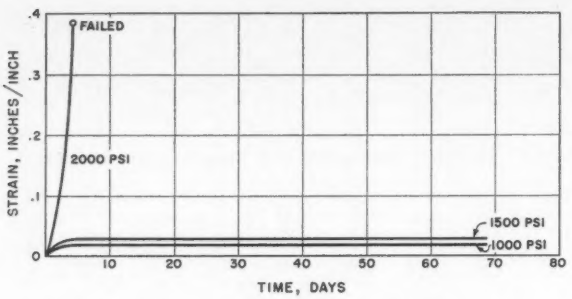


Figure 1—Creep tests of 80 F (Cellulose Acetate Butyrate).

TABLE 1—Typical Test Data—Constant Load Flexure Tests on Glass-Plastic Laminates

Sample	Resin Type	Flexural Strength in Air 75 F psi	Stress Applied in Test psi	Time of Failure Hours		
				75 F	150 F	
				Air	Air	Water
A	Polyester	51,300	25,700	213*	215*	1.9
B	Polyester	46,400	23,200	240*	74	0.2
C	Epoxy	81,500	40,800 25,700	.....	.....	1.3 22.9
D	Epoxy	79,100	39,500 25,700	.....	.....	50 576*

* Creep rate practically zero at indicated termination time.

served to fail at tensile stresses appreciably below their ultimate tensile strength as determined by short-term tests. Mr. Levinson concluded therefore that short-term data on thermoplastics are valid only for the length of time required to make the test and are of no value to engineering design. He also observed that the media to which plastics are exposed can seriously alter the physical properties of the material. Thus, the reported creep data on thermoplastics in air would not necessarily be valid for the same materials in water, oil, or other media.

This does not imply that creep of thermoplastics under load was unknown until disclosed by T-1J. On the contrary, R. H. Carey[2] has shown clearly the wide difference between short and long-term properties of polyethylene. In addition M. L. Dannis[3] has reported detailed studies concerning creep of polyvinyl chloride under stress. T-1J does not believe, however, that these properties of plastics have been considered properly in the manufacture, advertising or use of structural plastics.

Properties of Thermosetting Resins

There is reason to believe that in many respects thermosetting plastics behave similarly to thermoplastics. R. S. Treseder[4] has reported in detail on constant load flexure tests on glass-plastic laminates. The data reported are illustrated in Table 1. These data are significant in several ways. First, glass-plastic laminates employing both polyester and epoxy resins fail under constant flexure loads at stresses far below their ultimate short-term flexure strength. Second, materials of this type will fail much more rapidly in water than in air. Wide differences between short-term and long-term strength of glass-plastic laminates also was demonstrated in work reported by The Atlantic Refining Company.[5] This work indicated that the long-term strength of a particular glass-reinforced polyester was less than 50 percent of the short-term values in regard to both tensile and compressive stress.

From these data, it is obvious both thermosetting and thermoplastic materials exhibit properties which may be considered unusual in a structural material. Failure to recognize this fact or inability to design in accordance with these findings almost certainly will lead to premature failures.

Engineering Data

Recognizing this, T-1J has actively and consistently urged manufacturers of resins or finished structural plastic products to report adequate long-term strength data on their materials or products. Development of such information is a major undertaking even if consideration is limited to a single resin formulation or product. If valid engineering data are to be obtained, tests must be conducted in the media in which the product is to be used and consideration must be given to other pertinent variables such as temperature. In preparing specimens care must be taken not to alter the structural strength of the product and stresses must be applied so they may be correlated with stresses encountered in actual use.

Long-Term Strength—PVC

Much of the experimentation reported to date has been of theoretical nature and is difficult to translate to engineering practice. A report by J. F. Malone[6] of the B. F. Goodrich Chemical Company discusses to some extent engineering significance of the previously cited work of M. L. Dannis. Mr. Malone shows that rigid vinyl plastics, Geon 8750 and Geon 8700 are suitable for use with tensile stresses up to 2500 psi and 2200 psi respectively though their ultimate strengths are 7000 psi and 5800 psi. These critical values were determined in air at room temperature. He also shows that creep continues to occur even within these limited stress ranges. Long-term creep behavior below critical stress was described mathematically by Mr. Dannis in terms of a time-dependent modulus. He states that proper use of this mathematical relationship would allow calculation of the expected elastic stretch and creep of unplasticized polyvinyl chloride under given load conditions after any specified elapsed time. Such calculations have obvious value in engineering design.

Long-Term Strength—Tenite Butyrate

Another such test program is being conducted by the Tennessee Eastman Company to determine the long-term properties of their cellulose acetate butyrate resins. Data available to date have been reported to the committee by L. W. A. Meyer and R. J. Scogin.[7] Results are reported in a manner quite similar to that employed by Mr. Levinson. The tests differ, however, in that lengths of pipe were used as test specimens and stress was applied by water pressure in the samples. Barlow's formula was used to calculate stress. Typical results are presented in Figures 2 and 3. The maximum stress which could

be imposed without continuing creep was called optimum. A summary of tests completed to date is shown in Table 2. Again, the difference in short and long-term strength is noted. An indication of the effect of temperature changes also is afforded. This test program is continuing toward definition of optimum hoop stress values for various Tenite Butyrate formulas at various temperatures.

Field Experience

The second approach taken by the committee was the compilation of data concerning the actual field performance offered to date by presently available structural plastic products. Data concerning plastic line pipe, plastic tankage and plastic tubing were obtained through questionnaire surveys. It was the committee's thought that the information amassed through these studies would indicate to some extent the amount and type of additional effort needed and the manner in which future studies should be conducted.

Data obtained through questionnaire surveys have been presented in four reports (8 and appendices 1, 2, 3). While there is far from enough service experience to define the values and limitations of structural plastics in the oil industry, the data obtained are of interest and definitely establish the fact that plastics can be employed successfully in oil production.

Thermoplastic Line Pipe

To date the most common application of structural plastics by the oil industry is as line pipe. Data have been obtained on 73 installations of thermoplastic (extruded) line pipe. Of these 73, one employed polyvinyl chloride pipe, 20 used styrene copolymer and 52 used cellulose acetate butyrate pipe. The data obtained have been summarized in Table 3. These 73 installations included more than 110,000 feet of plastic pipe. Twenty-four (33 percent) experienced one or more failures, usually during the first few days of operation. Nineteen of the 24 installations suffering failure were successfully repaired and returned to service. Thus, in only 5 of 73 installations have failures been so serious that the line could not practically be repaired.

It is noted that 10 failures are blamed by the users on excessive temperature, pressure, or thermal expansion. Calculations indicate that only in one case did hoop stress exceed 2000 psi and in only one instance was the temperature in excess of 120 F. Thus eight failures of thermoplastic pipe occurred at stress levels far below the short-term ultimate strength of the materials employed. This serves further to verify the inadequacy of short-term strength data.

Thermosetting Line Pipe

Reports have been received on 28 installations of line pipe manufactured from glass-fiber reinforced thermosetting resins. Seven of the installations were experimental and include less than 30 feet of pipe. The remaining 21 installations included over 2500 feet of pipe ranging in size from 3 inches to 4½ inches. Table 4 briefly summarizes the service rendered by these 21 installations. It is difficult and perhaps inaccurate to attempt to reach general conclusions on the basis of these limited data. It is interesting to note, however, that the nine installations which have not experienced failure are, without exception, operating at internal pressures below 60 psi and at atmospheric temperatures. Certainly, the relatively high failure frequency emphasizes the need for adequate engineering design data.

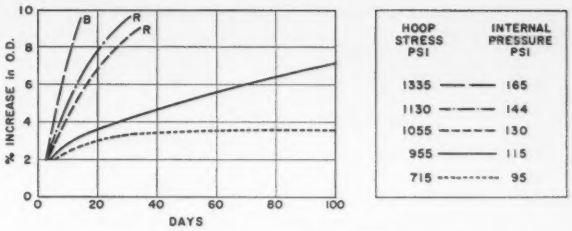


Figure 2—Creep of 2-inch SWP Tenite Butyrate pipe (wet) at 70-100 F.

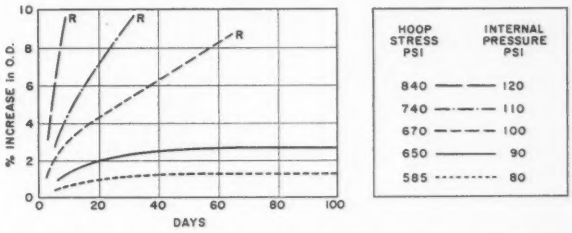


Figure 3—Creep of 3-inch IPS Tenite Butyrate Pipe (wet) at 120 F.

TABLE 2—Summary of Hoop Stress Range at Test Temperature for Two Different Formulations of Butyrate Pipe

Group	Hoop Stress Range psi	Tensile Strength at Fracture, psi
A	895-1055 at 70–100 F	4680 at 100 F
B	715-900 at 70–100 F	4460 at 100 F
C	760-845 at 120 F	4020 at 75 F
D	650-755 at 120 F	4060 at 75 F

TABLE 3—Summary of Field Experience. Thermoplastic (Extruded) Pipe

No. of Installations	73
Pipe Footage (Total)	>110,000
No. of Failures	24
Installations Retired Because of Failure	5
Cause of Failure	
Misapplication	2
Excessive Temperature and/or Pressure (includes thermal expansion)	10
Faulty Manufacture	12

TABLE 4—Summary of Field Experience. Thermosetting Glass-Reinforced Line Pipe

No. of Installations	21
Total Footage	>25,000
No. of Failures	12
Cause of Failures	
Thermal Expansion	3
Excessive Pressure	2
Excessive Temperature	2
Excessive Temperature and Pressure	1
Faulty Manufacture	2
Other	2

In-Hole Tubing

Data on 12 installations where plastic tubing was selected for down-hole use in wells were reported to

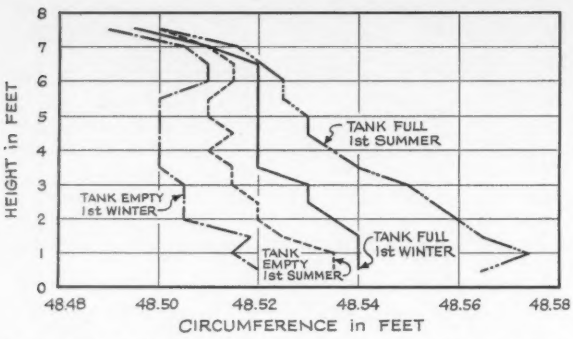
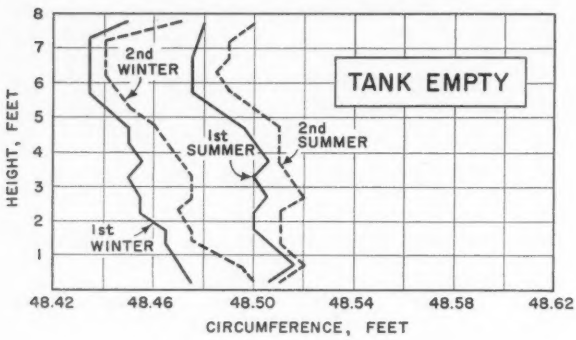


Figure 4—Circumferential measurements of glass-polyester stock tank.



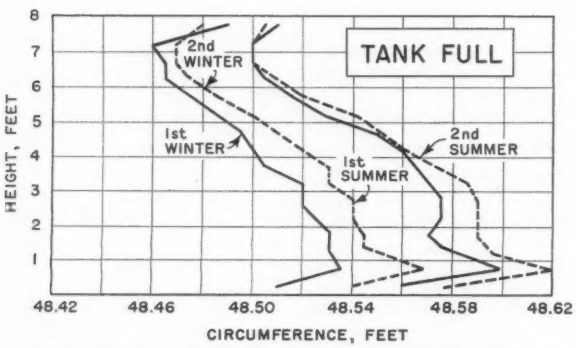


Figure 5—Circumferential measurements of glass-epoxy tank.

the committee. Results at the time of the questionnaire are given in Table 13 herein.

More recent data have disclosed failure of a third string of reinforced thermosetting tubing employed in a slat water disposal well. So far, no reported installation has served satisfactorily for as long as two years. Thus it can be concluded that the performance of plastic tubing in oil wells or salt water disposal wells has been disappointing. A majority of the committee feels confident, however, that advances are being made which ultimately will provide material suitable for down-hole use.

Plastic Tanks

Data on 11 plastic tanks have been reported to the committee. At the time of the survey, the oldest of these had been in service only one year, six had served 10 months, two only one month, and two others were under construction. These short service histories are, of course, inadequate for evaluation of plastic tanks. While all 11 of the tanks were still in service, reports and comments by their owners indicate that changes are occurring which ultimately may lead to serious failures.

One user supplied the data shown in Figures 4 and 5 to illustrate changes which occurred to a 250 bbl. glass-polyester tank and 250 bbl. glass-epoxy tank. The data shown were obtained by measuring the circumference of the tank at 6-inch intervals vertically. Measurements were made with empty and full tanks during both summer and winter operations. As shown, in Figure 4, the circumference of the glass-polyester tank was greater, under both empty and full conditions, during the first summer than the preceding winter. Since the coefficient of thermal expansion does not account for all this stretch, the owner reasoned the material had permanently deformed due to repeated loadings. This reasoning appears to be confirmed by the second winter stripping when expansion due to temperature was essentially eliminated. Thus, it appears that creep is taking place and may, of course, be indicative of future failure.

Figure 5 shows similar data on a like-sized glass-epoxy tank. Although the magnitude of change is not so great, the same phenomena occur and conceivably can lead to unsatisfactory results.

Conclusion

It is obvious from the preceding discussion that T-1J has a tremendous remaining task if it is to define the values and limitations of structural plastics to the oil-producing industry. Only a very small amount of reliable engineering data are available. Because of this, installation of plastic pipe, tubing and tankage has been limited to small experiments or to instances where prior field experience has shown that conditions are not too severe for their satisfactory service. Because of many pertinent variables and types, it is highly improbable that plastic products employed in this manner will prove of great benefit in oil production. If major service is to be rendered by these materials engineering data adequate to allow their use to the limit of their capabilities must be available.

The data which have been reported by Mr. Malone and by Messrs. Meyer and Scogin are certainly beneficial in this regard. T-1J will continue to encourage and solicit reports of this nature. It also is anticipated that efforts to amass and maintain up-to-date records of field performance will continue. It is the committee's hope that these studies ultimately will allow the use of structural plastics in oil production with the engineering confidence now enjoyed with more conventional materials of construction.

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APPENDIX 1

Report No. 7 of T-1J

Service Experience of 11 Oil Field Installations Of Glass Reinforced Plastic Tanks

Abstract

Data cover two types of laminates in both constant load and fatigue type tests. Although the tests were not complete at the time the data again indicated the large difference in short-term strengths in air and the long-term strengths in the service environment. In this case fatigue strengths seemed higher than stress rupture strengths thereby indicating repeated tank fillings might not be a more severe service than a tank continually full.

THIS report summarizes oil field experience with glass-reinforced plastic tanks. Questionnaires on this subject were sent to 61 NACE members of T-1 and T-1J. Eight replies were received from five companies covering eleven different tank installations. In addition, two reports contained comments on eight other plastic tank installations which are covered in the Comment section of this report.

Description of Tanks in Survey

All tanks covered by this report are of the bolted 250 or 500-barrel design. Nine tanks (5-250 bbl., 4-500 bbl.) were of the glass mat-polyester construction and two (250 bbl.) were of the glass roving-epoxy laminate.

The laminate thickness of the glass mat-polyester tanks reported by users varied considerably as shown in Table 5.

The manufacturer recently advised (May 1954) that tanks produced at that time are all being equipped with staves having a 0.20-inch wall thickness containing four layers of 2-ounce per square foot. This combination was considered satisfactory for use in both 250 and 500-bbl. applications.

The material thickness in both glass roving-epoxy tanks was 0.125-inch in all parts, with twice that thickness in the bolt line. The staves contained two layers of horizontal glass roving and one layer of vertical roving.

Length of Service

At the time of reporting on service experience, two of these tanks (500 bbl.) had just been received and were under construction; two tanks (250-bbl. epoxy) had been in service one month; six tanks (2—500 bbl., 4—250-bbl.) had been in service about ten months and one 250-bbl. tank had been in use approximately a year.

Type of Service

The type of service in which these tanks are serving is shown below:

Service	Number, Size and Type Tank
Salt Water Disposal Settling Tank	1—250 Bbl.
Water Flood Storage Tank	1—250 Bbl.
Oil Field Stock Tank	3—250 Bbl., 2—250 Bbl. (epoxy)* 4—500 Bbl.

* Epoxy laminate tanks designated in this manner in all tables.

Reported operating temperatures of fluids in these tanks are shown in Table 6.

Strappings

The number of strappings and results by tanks are shown in Table 7.

One user supplied pictures and strapping data to illustrate the changes reported above to both a glass-polyester (250 bbl.) and glass-epoxy (250 bbl.) tank. These strappings, which were undertaken to evaluate the materials in field service, consisted of strapping the tanks empty and full during summer and winter operations by measuring the circumference at 6-inch intervals of height. The staves were reported as 0.15-inch thick and contained three layers of fiber glass mat weighing 3 ounces per square foot. Figure 4

TABLE 5—Thickness of Tank Members by Installations

Material Thickness	0.125″	0.14″	0.20″	Unanswered
Stave	3	1	0	5
Bottom	1	1	2	5
Top	3	1	0	5

Bolt Line Thickness	0.125″	0.165″	0.18″	0.20″	Unanswered
Stave	2	1	0	1	5
Bottom	0	1	1	2	5
Top	2	1	1	0	5

TABLE 6

Temperature Degrees F	Number	Size Bbl.	Type
Atmospheric	2	250	(Polyester), 2-250 Bbl. (epoxy)
0-110	1	250	
80	2	500	
100	1	250	
100-120	1	250	
Unanswered	2	500	

TABLE 7—Strappings

The number of strappings and results by tanks are itemized below:

Number of Strappings	Number	Size Bbl.	Type	Changes No.	Noted Yes
1	2	500	2-250 Bbl. (epoxy)	2	2 epoxy
2	1	250	.....	1	....
3	1	250	....	....	1
4	1	250	....	....	1
Unanswered	1	250	2-500 Bbl.	....	....
0	1	250	....	1	....

shows the results of strappings on this tank during two winters and one summer. The difference in circumference under empty and full conditions was attributed to creep under load. As shown, the tank circumference was greater, under both empty and full conditions, during the first summer than the previous winter. Since the coefficient of expansion does not account for all this stretch, it was believed after the summer strapping that the material had permanently deformed due to repeated loadings. This was confirmed by the second winter strapping when expansion due to temperature was essentially eliminated and yet the tank was slightly larger than during the first measurements. From these measurements, it was calculated that the tank capacity, when full, was 0.152 percent greater in summer than the first winter and the average summer and winter difference between empty and full capacity is 0.188 percent. Although the maximum industry tolerance is only 0.10 percent, these volume change characteristics can be adjusted and would not deter adoption of plastic tanks for oil field service.

Measurements on a like-size glass-epoxy tank which has been strapped (shown in Figure 5), indicate a volume change between empty and full conditions of about one-half that mentioned above. That is comparable to changes observed in bolted steel tanks. Effect of creep, of course, will not be indicated until subsequent measurements are made.

Estimated Payout Time

The questionnaire also sought the estimated payout time of each plastic tank installation along with the type of tank used for calculating that time. A summary of the replies is shown in Table 8.

Foundation

The questionnaire also inquired of the type of foundation used for plastic tanks; i.e., concrete or earthen. All replies indicated the use of earth foundations except for two 500-bbl. and one 250-bbl. tank installation concerning which there was no answer to that portion of the questionnaire.

TABLE 8

Tank of Comparison	Number	Size Barrel	Type	Payout Time, Years
Galvanized, Coned Bottom	2	500	....	Not figured
Bare Steel	2	250	(epoxy)	12
	1	250	....	10
Galvanized, Coned Bottom, Aluminum Deck	1	250	....	1.5
Galvanized, Flat Bottom	1	250	....	5
Galvanized, Aluminum Deck	1	250	....	8.5
Unanswered	2	500	....	....
	1	250	....	....

TABLE 9

Reply No.	No.	Size Bbl.	Service	Oper. Temp. F	No. Times Strapped	Changes Noted	Payout Years
1	1	250	Oil Field Stock	0–110	3	Yes	10
2	2	250	Oil Field Stock	80	At Least Once	No	Not Given
3	1	250	Oil Field Stock	Atm.	4	Yes	1.5
4	2	250[1]	....	....	....	....	....
5	1	250	Oil Field Stock	Atm.	Not Given	No	8.5
6	1	250	Water Flood Storage	100–120	None	No	Not Given
7	1	250	Salt Water Disposal Settling	100	2	No	5
8	2	250[2]	Oil Field Stock	0–110	1	Yes	12

[1] Under construction.
[2] Epoxy.

Comments

The final information sought by the questionnaire was a description of the nature and cause for any failure or peculiar appearances which may have occurred. Data are given in Table 9. Comments are itemized below by installations:

Reply 1—Difficulty was encountered in eliminating leakage around bottom chime when this tank was erected.

The tank has been strapped at intervals of approximately one month by the pipeline company running the oil from the tank. It also has been strapped once under both winter and summer conditions for calibration purposes. The summer strapping revealed that the tank had expanded somewhat since the winter strapping. The nature and magnitude of this expansion is such that it is believed to result from a combination of both the temperature difference and the effect of continued use of the tank.

Inspections, made subsequent to the tank's erection have revealed: 1) The deck has sagged somewhat 2) A minor seam leak has developed; 3) The bottom chime has settled slightly around the bottom; and 4) One of the staves has three cracks which do not yet leak and one stave has a single horizontal crack that leaks very slightly. All of these cracks are in the upper half of their respective staves. The three cracks are irregular in direction and approximately 14 to 20 inches in length while the single crack is only about one inch long. None of these defects have impaired the usefulness of the tank.

Reply 2—Tanks were unsatisfactory and were replaced in February 1954 with same type tanks. Upper rings and decks were in good shape. Lower rings, stave joints, and center chimes seeped oil and could not be corrected; made messy installation. Tank erector said stave gaskets used in old tanks were too thick and that caused seepage. Plumb bob made no dent in old tanks. Old tanks had metal hoops on outside.

In new tanks minor leaks still occurring but are being fixed as they appear by tightening staves satisfactorily. Design of new tanks changed in staves although deck and bottom are the same. Increased thickness of staves to 0.1875-inch and tapered to 0.625-inch on ends. Staves are butted together and two bolts used instead of one as in old tanks. The new tanks have no hoops, the design being such that the more pressure on the inside, the tighter the seal. Tanks look as if they will be very satisfactory.

Reply 3—No failures have occurred to date. However, the following have been noted: 1) Thermal expansion has occurred. 2) The tank material has undergone permanent stretch. 3) The elasticity of the tank material has increased.

Reply 4—Tanks (2—500 bbl.) under construction.

Reply 5—No adverse report to date.

Reply 6—No failures to date, they appear to be in good shape.

Reply 7—In March 1953 the deck was found to be in a concave rather than the conventional convex position and the two joints of glass-reinforced polyester pipe supporting the deck were found on the floor of the tank. The tank deck was jacked back to its normal shape and the supports were bolted in place. The inversion appeared to have no adverse effect on the tank. The tank was strapped prior to this trouble and after with no significant difference noted.

Reply 8—Some difficulty was encountered in eliminating leakage at the seams of both tanks.

Miscellaneous Reports Submitted Along With Returned Questionnaires

No. 1—April 1954—A visit was made to an adjoining lease where a 500-barrel polyester tank was in operation as a wash tank. The bottom stave appeared ready to burst at any moment. It appeared to have a bow of about 2/3 inches beyond the bottom circumferential bolt line. No cracks or leaks were apparent at any place on this tank. However, only a very superficial examination was made.

No. 2—July 1953—For your information and further distribution, we submit the following brief memorandum report, concerning a H-500 barrel glass laminated polyester tank. The tank was erected on a cement ring foundation with the interior filled with sand. Steel hoops were placed on the lower ring for additional support. The tank was to be tested by completely filling with water, however, after approximately 300 barrels had been placed in the tank, the lower ring completely collapsed. Examination of the foundation, following the rupture of the tank, revealed that it was completely intact. Representatives of the manufacturer related that they were redesigning their bottom ring to eliminate this problem; however, none of these new design features were discussed. In addition, six L-250 barrel polyester plastic tanks were erected on cement foundations and tested in a similar manner and no failures occurred.

Conclusions

Manufacturers of these tanks have reported verbally to the co-chairman that they have conducted yard tests on their products as well as tensile tests on dry specimens (also on specimens dried after immersion) cut from standard production. In addition, available also are these very fine descriptive service tests which are helpful in selecting tankage.

However, none of these data provide the quantitative information needed for design purposes. It has been shown by previous reports to this committee that plastics, both extruded and reinforced, slowly creep under stress and that the long term strength may be considerably less than the short term measured values. Therefore, it seems that stress-strain-time curves should be developed to determine the long term strength of plastic tank materials in water at various temperatures and since repeated fillings will occur it seems the wet fatigue strength also should be determined. Otherwise it will be difficult to predict how many years the tanks can withstand service stresses.

Addendum

Since preparation of Report No. 7 on July 28, 1954, an additional summer strapping has been secured on both the 250-barrel glass-polyester and glass-epoxy tanks. These data have been added to Figures 4 and 5 to provide the latest information on these tanks.

APPENDIX 2

Report No. 8 of T-1J

Service Experience of 28 Oil Field Installations Of Glass Reinforced Plastic Pipe

Abstract

This report presents data obtained by questionnaire survey. The data on centrifugally cast pipe show that failures have occurred in 57 percent of the 21 reported installations. The data further indicate that the service of these materials is adversely affected by temperatures above atmospheric and pressures above 100 psi.

THIS REPORT presents data concerning field service of glass reinforced plastic pipe obtained through questionnaire survey.

Reports have been received from nine companies describing 28 pipe installations. Twenty-one were installations of centrifugally cast pipe. The other seven used pipe manufactured by wrapping resin-soaked fibers around a cylindrical mandril. The latter type material will be referred to as "laminated" in this report.

Laminated Pipe

The installations of "laminated" pipe were few and all were test installations. Only one of seven such installations suffered failure. This particular installation included 30 feet of 2¼-inch pipe in a salt water disposal line. The wall thickness was 0.25-inch. Pipe was buried and threaded couplings were employed. Temperature ranged from 65 to 85 F and pressure was from 600 to 650 psi. Water, at the rate of 700 B/D was handled by the line. This line was reported to have failed as a result of excessive pressure. The remaining six installations of laminated pipe ranged in length from three inches to 15 inches; in outside diameter from 2¼-inch to 8¾-inch; and in wall thickness from 0.125-inch to 0.1875-inch. Service temperatures were from 60 to 95 F and pressures were from —6 psi to 10 psi. Fluids handled included sweet and sour brine, oil and gas. None were buried and all were connected with a slip-coupling which allowed contraction and expansion. As has previously

been stated, all six installations have served without failure.

Cast Pipe

The dimensions of the 21 installations of centrifugally cast pipe are shown in Table 10.

Seventeen of these installations were for corrosion control, one for paraffin and corrosion control, one for paraffin control and two for scale control. Five were flowline installations, five were tank battery connections and the remaining eleven were employed in water disposal or flood operations. A complete tabulation of data obtained concerning these 21 installations is shown in Table 11.

Failures occurred in 57 percent, or 12 of the 21 installations. Causes of failure, as given by the operators were as follows:

Cause	No. Installations
Thermal Expansion	3
Excessive Pressure	2
Excessive Temperature	2
Excessive Pressure & Temperature	1
Faulty Pipe	2
Other	2

The three failures which were attributed to thermal expansion occurred in lines which were installed without slip couplings to absorb thermal stresses. Failures occurred in lines 500, 550 and 2000 feet in length. Service temperatures ranged from 50 to 140 F with differentials as high as 40 F. There were 16 additional installations without slip couplings for protection from thermal expansion. Nine of these were reported to have failed from causes other than thermal expansion. Seven have experienced no failure. These seven saitsfactory installations include lengths up to 4000 feet and service temperatures ranging from 80 to 120 F. Temperature differentials were as great as 30 F. Thus, there appear to be no definite criteria to indicate necessity for use of slip couplings to compensate for thermal expansion.

Excessive pressure was listed as the cause of two failures and a combination of excessive pressure and temperature was blamed for a third. These three installations were subjected to maximum internal pressures of 200, 100, and 93 psi. Operating temperatures for the first two were atmospheric and were as high as 120 F for the third. It may be significant that these three installations were operating at pressures higher than those reported for any of the other 18 installations. The next highest pressure reported was 60 psi.

Two installations were reported to have failed due to excessive temperature. These operated at average temperatures of 100 F and 200 F with maximum temperatures of 140 F and 220 F respectively. A third installation which failed from a combination of excessive temperature and pressure previously has been described. There were only two additional installations with average operating temperatures above 100 F. Both of these failed from other causes. It may be significant to note that none of the nine installations which did not experience failures were subjected to average operating temperatures in excess of atmospheric.

The two failures which were listed as the result of faulty pipe were repaired and placed in satisfactory service. The failures were reported to have been caused by interior cracks and imperfect ends which resulted in collar leaks. Approximately 10 leaks occurred in the two installations.

One installation failed as a result of insufficient longitudinal beam strength. The line was run on the surface in a sand area. Sufficient sand was blown from under the pipe to allow sagging and failure. The line subsequently was buried to a depth of 6-inches and has served satisfactorily since. Another failure

TABLE 10

No. Installations	Pipe OD (In.)	Wall Thickness (In.)	Total Length (Ft.)
1	3	.....	2000
1	3	0.28	2000
4	3	0.20	12200+
3	3½	0.125	1460
2	3½	0.20	610
5	3½	0.25	5015
2	3½	0.28	240
1	4	0.28	1500
1	4½	0.125	260
1	4½	0.20	60
			25,345+

TABLE 11—Field Performance of Centrifugally Cast Glass Fiber Reinforced Plastic Pipe

Installation*	Purpose of Installation	Length Ft.	Size (OD. in.)	Wall Thickness (in.)	Date Installed	OPERATING CONDITIONS Temp. Avg. (°F)	Temp. Max. (°F)	Press. Avg. (psi)	Press. Max. (psi)	Type Coupling	Type Connection With Steel	Pipe Buried	Failure	Cause of Failure
SWDL	Corrosion	1500	4	0.28	8-51	90	120	55	60	Victaulic	Victaulic	Yes	No	.....
FL	Corr. & Paraffin	1000	3½	0.125	4-53	80	140	25	40	Slip-on	Thread Adapter	No	Yes	Excessive Beam Load
SWDL	Corrosion	2000	3	0.28	12-51	Atm.	Atm.	150	200	Threaded	Thread Adapter	Yes	Yes	Excessive Pressure
SWGL	Corrosion	8000	3	0.20	4-52	Atm.	Atm.	30	40	Threaded	Thread Adapter	Yes	Yes	Corroding Clamps
TB Conn.	Corrosion	200	3	0.20	4-52	Atm.	Atm.	30	40	Slip-on	Thread Adapter	No	No	.....
SWDL	Corrosion	4000	3	0.20	5-53	Atm.	Atm.	30	40	Threaded	Thread Adapter	Yes	No	.....
SWDL	Corrosion	.....	3	0.20	9-53	Atm.	Atm.	..	....	Threaded	Thread Adapter	Yes	No	.....
TB Conn.	Corrosion	550	3¼	0.20	2-52	120	140	20	30	Slip-on	Thread Adapter	Yes	Yes	Thermal Expansion
SWDL	Corrosion	60	4½	0.20	1-53	70	90	70	100	Victaulic	Thread Adapter	No	Yes	Excessive Pressure
SWGL	Scale	60	3½	0.20	11-52	100	140	0	0	Threaded	Thread Adapter	No	Yes	Excessive Temperature
SWGL	Corrosion	2000	3	.....	10-53	100	110	20	20	Slip-on	Flanges	No	Yes	Thermal Expansion
SWDL	Corrosion	260	4½	0.125	4-53	115	120	93	93	Slip-on	Thread Adapter	Yes	Yes	Excess. Press. & Temp.
FL	Corrosion	1700	3½	0.25	11-52	80	110	15	30	Slip-on	Thread Adapter	Yes	Yes	Faulty Pipe
FL	Corrosion	265	3½	0.25	9-52	80	110	15	30	Slip-on	Thread Adapter	Yes	Yes	Faulty Pipe
FL	Corrosion	2000	3½	0.25	9-52	30	110	15	30	Slip-on	Thread Adapter	Yes	No	.....
FL	Paraffin	500	3½	0.25	9-52	50	90	35	60	Slip-on	Thread Adapter	No	Yes	Thermal Expansion
SWGL	Corrosion	550	3½	0.25	10-53	60	110	5	5	Threaded	Thread Adapter	Yes	No	.....
SWDL	Corrosion	40	3½	0.28	6-52	70	100	20	20	Threaded	Flange	Yes	No	.....
TB Conn.	Scale	200	3½	0.28	12-53	200	220	20	20	Slip-on	Flange	No	Yes	Excessive Temp.
TB Conn.	Corrosion	230	3½	0.125	6-53	80	212	1	1	Slip-on	Dresser	Yes	No	.....
TB Conn.	Corrosion	230	3½	0.125	6-53	80	212	1	1	Slip-on	Dresser	Yes	No	.....

* FL—Flow Line.
SWDL—Salt Water Disposal Line.
SWGL—Salt Water Gathering Line.
TB Conn.—Tank Battery Connection.

TABLE 12

Effect of Burying Pipe	No Installations	No Failures	Percent Failures
Buried	14	6	43
Not Buried	7	6	86
Coupling Method:			
Victaulic	2	1	50
Threaded	7	3	43
Slip-on	12	8	67
Type Service:			
Flow-line	5	4	80
Tank Battery Connections	5	2	40
Salt-Water Gathering	4	3	75
Salt-Water Disposal	7	3	43
Installation Date:			
July-Dec. '51	2	1	50
Jan.-June '52	4	2	50
July-Dec. '52	5	4	80
Jan.-June '53	6	3	50
July-Dec. '53	4	2	50

was caused by the use of magnesium alloy clamps as connections. Corrosion of these clamps caused the pipe to be crushed and resulted in failure of the line.

The relatively small number of installations included in this survey makes statistical analysis of results difficult and perhaps of little value. Certain interesting factors, however, were examined with the results shown in Table 12.

While it is doubtful that sufficient installations were included in this survey to allow much significance to be placed on the data in Table 12, it does appear, however, that it might be reasonable to conclude that reinforced pipe should be buried. Little significant correlation is apparent from the data concerning coupling method, type service, or installation date.

In consideration of these data, no attention has been given factors such as resin formulation, glass content and configuration and glass sizing. These factors obviously are pertinent to the performance of reinforced plastic products but their effect cannot be assessed from the data at hand. The purpose of T-1J is to define the value of structural plastics to the oil producing industry and to provide those engineering data necessary for intelligent application of structural plastics within their limitations. While these data leave many questions unanswered, they do offer some valuable indications. It is apparent that the materials included in this study are adversely affected by temperatures above atmospheric and pressures above 100 psi. These limitations must be accurately defined before reinforced plastic pipe can safely be used to full advantage in the oil producing industry.

APPENDIX 3

Report No. 9 of T-1J

Oil Field Structural Plastics

Abstract

This report presents data obtained by questionnaire survey. The few reported installations do not allow general conclusions to be drawn concerning the economic value of plastic tubing. At the time of the questionnaire survey, five installations were serving without history of failure. These five installations were between 3003 and 3860 feet in length. Two had served 16 months, one 12 months, one 9 months and one 6 months. All were centrifugally cast glass reinforced tubing used as induction strings in salt water disposal wells.

THIS REPORT presents those data obtained by questionnaire survey concerning the down-hole use of plastic tubular products by the oil producing industry. Descriptions of 12 such installations have been received. Four employed tubing extruded from thermoplastic materials and eight employed glass fiber reinforced thermosetting materials. One of the latter installations employed tubing manufactured by wrapping resin-soaked fibers around a cylindrical mandril. Tubing used in the other seven installations was manufactured by centrifugal casting.

Four of the 12 installations employed plastic tubing as tail pipe in pumping oil wells. The other eight descriptions concerned the use of plastic tubing as induction strings in salt water disposal service. A tabulation of data obtained is shown in Table 13.

Extruded Thermoplastic Tubing

Only one of four installations of extruded tubing was reported to have served without failure. This installation included 7 feet of 1½-inch butyrate tubing used as tail pipe in a pumping oil well. The

TABLE 13—Field Performance of In-Hole Installations of Plastic Tubing

Type Tubing	Use	Footage	Size OD (In.)	Wall Thickness (In.)	Type Coupling	Date of Installation	Completion Method	Fluid in Annulus	OPERATING CONDITIONS				Type Failure
									Sur. Press. (psi)		Temp. (°F)		
									Tbg.	Ann.	Sur.	B.H.	
Extruded-Thermoplastic	Tail Pipe in Pumping Well	7	1½	....	Threaded	11-52	Hung-Open End	.....	55	....	95	105	None
"	SWD Well, Induction string	4500	2.87	0.253	Threaded	1-50	Hung-Open End	Light Hydrocarbon	—14	Atm.	Atm.	110	Parted 120' below surface—Not repaired.
"	Tail Pipe in Pumping Well	1079	2¼	0.125	Theraded	7-51	Perforated	.....	35	0	80	105	Split collars abrasion—Not repaired.
"	"	902	2¼	0.125	Threaded	7-51	Perforated	.....	35	0	80	105	Split collars abrasion—Not repaired.
Laminated Glass-Reinforced	"	150	2⅞	0.125	Threaded	3-52	Perforated	.....	35	0	80	105	Joints unscrewed—Not repaired.
Cast Glass-Reinforced	SWD well, Induction string	3021	3½	0.1875 0.28	Threaded	12-52	Hung-Open End	Light Hydrocarbon	Vac.	0	60	100	None.
"	"	2985	3½	0.28	Threaded	11-53	Set thru Packer	Inhibited Water	—13	0	75	95	3 Failures during installation—Not repaired after third failure
"	"	3500	3½	0.28	Threaded	5-52	Set thru Packer	.....	100-150	....	Atm.	....	None.
	"	3550	3½	0.28	Threaded	10-52	Hung-Open End	Light Hydrocarbon	0	0	70	....	None.
"	"	3003	3½	0.28	Threaded	4-53	"	"	0	0	68	85	None.
"	"	3435	3½	0.28	Threaded	2-53	"	"	0	25	68	85	Internal cracks and exposed fibers—Satisfactorily repaired.
"	"	3860	3½	0.28	Threaded	1-53	"	"	Vac.	....	Atm.	100-110	None.

tubing was hung open-ended at 2000 feet in a well producing sweet oil and water. The installation was completed in November 1952 and as late as October 1953 was serving satisfactorily. Bottom hole temperature in the well is approximately 105 F. Two other installations of plastic tail pipe proved unsatisfactory. Both of these were of 2¼-inch styrene co-polymer tubing and were installed in July 1951. One installation included 1079 feet of tubing and the other used 902 feet. Bottom hole temperature was approximately 105 F. Both were found to have failed in less than two months after installation. Failures resulted both from splitting of couplings and abrasion between tubing and casing. The operator expressed the opinion that the threaded couplings, which were manufactured by casting, failed because of an inherent weakness resulting from casting methods.

Only one report was received describing the use of extruded tubing as an induction string in a salt water disposal well. In January 1950, 4500 feet of butyrate tubing was run in a disposal well handling approximately 2400 barrels of sour water per day. This tubing had a 2.87-inch OD, a wall thickness of 0.253-inch, and weighed 1.22 lb/ft. It was hung open-ended and the annulus was filled with a light hydrocarbon. Surface tubing pressure was 0 to 29-inches vacuum, and bottom hole temperature was approximately 110 F. Soon after the installation was completed, the fluid level in the annulus dropped from full to 1000 feet down indicating a tubing leak. The tubing was not pulled, however, until August 1952. At this time, the tubing was found to be parted at 120 feet below surface. The remainder of the string could not be recovered and the well was abandoned.

"Laminated" Tubing

Only one installation of reinforced tubing manufactured by wrapping fibers around a cylindrical mandril was reported. This installation included 150 feet of 7⅞-inch OD tubing as tail pipe in a pumping well. This string was a mixture of two weights of tubing. One weight was 0.81 lb/ft with a 0.125-inch wall thickness and the other was 1.23 lb/ft with a 0.1875-inch wall thickness. Threaded couplings were used. This tail pipe was installed in March 1952 and removed in June 1953. It was found that the couplings had unscrewed and dropped the string to the bottom of the well. The pipe itself apparently was unaffected. No difference in the performance of the two weights of pipe was detected.

Centrifugally Cast Tubing

Reports have been received on seven installations of centrifugally cast glass fiber reinforced plastic tubing. In all seven instances, the tubing was employed as induction strings in salt water disposal wells. Two of the seven installations were reported to have suffered one or more failures. One 2985-foot string failed three times during installation. The tubing parted at 2820 feet, apparently from excess tension applied while attempting to pull tubing from a packer. This failure was repaired and the tubing rerun. The other two failures are believed to have resulted from excess collapse loads applied in attempts to fill the annular space above the packer with inhibited water. The tubing was not repaired after the third failure. The other string which was reported as having suffered failure was pulled for inspection shortly after installation. It was found that glass fiber reinforcing was exposed and hanging loose in several joints. Internal cracks also were found in several joints. These faulty joints were replaced and the tubing was serving satisfactorily at the time of the questionnaire report. Five installations were reported as having served without known failure. These tubing strings varied in length from 3003 to 3860 feet. At the time of the questionnaire survey, two of these five strings had been in service 16 months, one 12 months, one 9 months, and the fifth had served six months. One of the operators advised that failures could occur in the tubing string and not be reflected in operations. Such failures could go undetached for long periods of time.

There are few conclusions which could be reached from study of these data. It is possible that a later survey including additional installations and longer service periods would yield more meaningful data. Additional surveys will be given consideration in future work of T-1J.

APPENDIX 4

Laboratory Tests on Reinforced Plastic Tank Materials

Two types of materials have been tested:

1. Chopped fiber mat impregnated with a polyester resin.
2. Three-ply construction using roving and an epoxy resin. The two outer layers of roving are in the circumferential direction of the tank and the center ply vertical.

Two types of tests have been made:

1. Plate fatigue in which a rectangular section from the tank stave is clamped at its four edges on a shallow steel box so that the sample constitutes a tight cover. The exposed face from clamp to clamp is 6 x 8 inches. The box is filled with fresh water and pressure applied and released intermittently

TABLE 14—Plate Fatigue Tests

Material	Thickness, In.	Cyclic Press., psi	Max. Stress[7] psi	No. of Cycles	Permanent Set at 0 Press[6] In.	Observations
Glass fiber mat-polyester resin	0.191	35	15,500	<4,000	.....	Failed[1]
	0.195	25	10,500	44,000	0.180	Failed[2]
	0.171	25	13,900	17,000	0.126	Failed
	0.177	25	12,900	<5,000[3]	0.132	Failed
Roving-epoxy resin[4]	0.124	40	42,000	> 240,000	0.166	Terminated[5]

[1] Specimens failed by rupture through the plate initiating at the center of and following the long edge.
[2] Test interrupted for 2 to 4 days after each 7000 cycles.
[3] Test made at 110 F.
[4] Outer layers in 6-inch direction of plate.
[5] There had been very slight leakage through the plate face beginning at about 30,000 cycles. The rate of leakage did not seem to increase for the duration of the test. There was no rupture at the points of maximum stress on to inside. However, there was cracking of the inner layer along the short edges parallel to the fibers. Maximum stress in this area was 23,000 psi.
[6] Measured at center of plate after test.
[7] Formula for calculating stresses from "Formula for Stress and Strain" by R. J. Roark, page 181. Formula No. 41. Condition: All edges fixed, uniform load over entire surface. Measured flexural strength of glass mat-polyester material 28,500 psi and of roving epoxy material 62,800 psi circumferentially and 20,200 vertically.

(30 seconds on, 30 seconds off). A dial gage applied to the center of the plate indicates the bulging of the plate and permits following the increase in bulging with time.

Maximum stress is at center of long edge. All tests were made at 70 to 80 F except the one shown in Table 14.

2. Stress rupture tests in tension. For these tests dumbbell shaped specimens of 2-inch gage length with a cross section of 0.25-inch by plate thickness were used. The long dimension was in the circumferential direction of the tank stave. They were suspended from a frame, with dead weight applied and were surrounded with fresh water at 110 F in all tests but one. See Table 15.

TABLE 15—Stress Rupture Tests

Material	Stress On Specimen[1], psi	Test Conditions °F	Duration of Test, Days	Observations
Glass fiber-mat polyester resin	5720	Air, 70-80	25	Very slow creep
	5720	H_2O, 100	0.1	Failed
	2860	H_2O, 100	1.7	Failed
	2380	H_2O, 110	162[2]	No creep for last 78 days
Glass roving-epoxy resin	7950	H_2O, 110	51[3]	No creep for last 41 days

[1] Measured tensile strengths: Glass mat-polyester resin 11,700 psi; roving-epoxy resin 54,700 psi.
[2] Prior to these 162 days the specimen had been under a stress for 1980 psi for 45 days. For 37 days there had been no creep.
[3] Prior to these 51 days the specimen had been under a stress of 5680 psi for 16 days with no creep after initial elongation on application of load.

Tentative Procedures for Preparing Tank Car Interiors for Lining

*A Report by NACE Task Group T-3E-1 On Corrosion Control of Railroad Tank Cars**

THE APPLICATION of a protective coating to a tank car is similar in technique to the lining of any steel structure in many aspects. Good service results with tank car protective coatings are dependent upon good surface preparation. However, the design of a car and the use to which it is put, introduce certain problems which must be faced if satisfactory coating results are to be obtained. NACE Task Group Committee T-3E-1 has prepared the following list of tentative procedures as a guide to improved control of tank car corrosion. It should be remembered that certain of these suggested procedures apply to specific cases or types of service and may not be required on some cars.

I. Cleaning or Preliminary Steps

1. Tank car should be properly steamed and washed free of all previous ladings.
2. If car has hauled strongly alkaline products, the surface should be neutralized with dilute acid followed by thorough washing with water. With weakly alkaline products thorough washing with water is sufficient.

   A 2 percent solution of phosphoric acid is suggested for the neutralization. *Caution:* Phosphoric acid will change the surface of the steel and may have an adverse effect on the adhesion of the coating. Consult coating manufacturer before using this acid.

   With all-welded cars *only*, certain shippers and coating manufacturers have found that careful steaming and thorough washing with water was sufficient for cars which had hauled alkaline products and that acid neutralization was not required.
3. If car has hauled acid products, steaming and washing should be sufficient.
4. For cars previously used in a wax or sludge service, it is suggested that the car be steamed, blasted thoroughly and resteamed. A prebake may be substituted for the second steaming. The blasting suggested above is for mechanical removal and not for surface preparation. Prebaking should not exceed 400 F because of the presence of temperature sensitive materials such as wood and some insulations.
5. New cars of welded construction are prepared by removing all moisture and residual foreign matter such as oil or grease.
6. Residual old linings must be removed.
7. Prebake car to remove all contaminating or volatile materials. A top prebaking temperature of 400 F is suggested and the baking should be continued until all evidence of seepage is gone.

II. Inspection and Repair

1. All mechanical defects should be repaired. See "CAUTION" under paragraph 6.
2. With riveted cars, laps, loose or cocked rivets or seams should be tightened by swedging, peening or caulking as required.
3. Deep cavities such as the seam between the dome apron and tank should be filled and/or caulked tight with a material which will not interfere with the subsequent coating operation.
4. Welds should be thoroughly inspected and ground smooth only if there is a bad area, sharp projection or error in welder's work.
5. Grind all sharp edges to ⅛ to ¼-inch radius, paying special attention to the entrance to the inner tank.

* J. R. Spraul, General American Transportation Corp., East Chicago, Ind., chairman.

6. Grind open any imperfection in metal surface such as occluded slag or deep sharp-edged pits. If pits are too deep they should be filled by welding and weld ground smooth.

Caution: Consult tank car owner before performing any welding on tank. Any welding of this nature should be done in accordance with accepted Association of American Railroads practices. Specific reference to the repair of pitting is found in the newly proposed Appendix "R" of ICC Tank Car Specifications expected to be published soon under H. A. Campbell's Tariff No. 9.[1]

III. **Blasting for Surface Preparation**

Details for surface preparation are given in a report by NACE Technical Unit Committee T-6G on Surface Preparation of Steels for Organic and Other Coatings.[2]

IV. **Painting**

1. Apply prime coat by brush as soon as possible after blasting. Do not allow blasted surface to remain overnight.
2. Relief valves are removed, taken apart and each piece coated separately provided facilities are available for resetting the valve.
3. Outlet valves usually are removed and the exposed surfaces painted except for the seat, which must not be coated.
4. Eduction pipes, of cars so equipped, should be removed and properly coated on inner and outer surfaces. Pipes of special alloys usually do not require a coating.
5. When applying baked coatings to the interior, caution must be exercised to obtain adequate curing of the coating over bolster and anchorage areas because of the more rapid heat loss at these points.

References

1. Available from H. A. Campbell, Agent, 30 Vesey St., New York 7, N. Y.
2. Second Interim Report of Unit Committee T-6G on Surface Preparation of Steels for Organic and Other Coatings. NACE Publication 53-1. 13 pages. Available from NACE Central Office, 1061 M & M Bldg., Houston 2, Texas. $1.00 per copy.

Data to Complete Sour Oil Well Report Gathered

Reports on Plastic Coatings Are Now Being Circulated

Reports on epoxys, rigid vinyls, and chlorinated rubber protective coatings for resistance to chemical corrosion have been completed by Technical Unit Committee T-6A on Protective Coatings and Linings for Resistance to Chemical Corrosion. The completed reports are to be circulated to interested parties for additional comment and suggestions before being submitted for publication.

Reports on the following coatings are in various stages of preparation: heavy linings, vinylidene chloride polymers, phenolics, rubber and elastomer silicones, furane, polyesters, fluorocarbons and bituminous coatings (including asphalt and coal tar coatings).

Progress on the above reports were presented at the committee's meeting in Chicago in March.

Epoxys Water Sensitive

During the meeting a question about the water sensitivity of epoxy resins especially within four hours of setting time was asked. Several members of the committee commented on the question. They said that all epoxys are water sensitive until they are fully cured. The curing of epoxy resins is also a function of temperature and at temperatures below 50 F it is difficult to achieve a satisfactory cure even after several weeks. At times the top 1½ mils of a 3 mil film may be cured while the bottom 1½ mils layer may be soft. Many times outside exposure will cause spotting, but the substrate will be protected despite appearances.

Another question asked concerned the availability of internal coatings for pipes carrying natural gas. In discussing the question one member pointed out that vinyls are being used for this purpose. Another member reported that at least three companies are studying amine cured epoxy combinations for this application.

The committee was of the opinion that epoxy resins were of questionable value in applications with an environment of water at 180 F.

A member reported that one company has developed a spray-on lining technique for lining with polyethylene for protection against detergent solutions. Another member reported he had heard of a laboratory process in which a 3-5 mil vinyl base coat was covered with a sprayed coat of polyethylene and then irradiated to promote adhesion and used for the same protection.

Committees Invited To These Sessions

South Central Region: October 18-21, 1955, Shamrock Hotel, Houston, Texas. October 18 and 19 being reserved for Technical Committee meetings. To reserve meeting space notify: T. J. Hull, NACE, 1061 M & M Bldg., Houston.

Northeast Region Meeting: October 31-Nov. 3, 1955, Niagara Falls, New York. October 31 being reserved for Technical Committee meetings. To reserve meeting space notify: T. J. Hull, 1061 M & M Bldg., Houston. (Meetings must be scheduled by August 1, 1955.)

Western Region Meeting: November 17 and 18, 1955, Sir Francis Drake Hotel, San Francisco, California. To reserve meeting space notify: T. J. Hull, 1061 M & M Bldg., Houston.

Numerous Questions About Inhibitors Being Considered

Unit Committee T-1D on Sour Oil Well Corrosion currently is gathering data to bring the committee's 1952 report up-to-date. At the committee's meeting in Chicago March 10, several questions in connection with sour crude corrosion were asked and discussed. The questions asked are some of those that need to be answered in order to bring the former T-1D report up-to-date. Questions asked were:

1. Is it necessary in any case to flush inhibitors down with well fluids? Can we find field data to support the answer?
2. What is the best criterion of the amount of inhibitor to be used in a sour crude well?
3. What are pump costs as related to corrosion? Is corrosion really a factor?
4. In general, if an inhibitor is effective in one pool, will it be effective in other pools?
5. Are there sour fields which are not corrosive? If not, why not?
6. How can we predict corrosion in a sour crude field?
7. In high water producers, which is better —a water soluble (or dispersible) or an oil soluble inhibitor?
8. Should inhibitor be injected daily, semi-weekly, weekly, etc.?
9. How should wells be completed in known corrosive areas to protect against corrosion?

In discussing question,[1] a member reported that his company believes the practice of flushing inhibitors down with well fluid is necessary because they had ex-

(Continued on Page 71)

Data to Complete—

(Continued From Page 70)

perience in which no flush was used. Another member did not think that a large flush is needed because the fluid already in the tubing annulus tends to dilute the inhibitor. He did think, however, it is necessary to circulate the fluids at the time inhibitor treatment is initiated.

Testing of Inhibitors Reported

In discussing question 2, one member reported that his company uses one inhibitor in five wells and another in five other wells and compares equipment performance in these wells. He added his company also employs coupon tests, although these do not always give a true picture of inhibitor effectiveness.

Another member reported that his company uses only equipment performance records to determine inhibitor effectiveness. It was pointed out that coupon tests serve a useful purpose because they tend to encourage pumpers to treat wells properly. In discussing before and after inhibitor treatment costs, while several members expressed the thought that cost comparisons should not be used to evaluate inhibitors, other members thought they should be. In general, the committee agrees some cost data are needed.

Damage to Pump Barrels

Regarding question 3, the effects of top or bottom pump hold-downs in corrosion of pump barrels was discussed. One member pointed out that severe corrosion often is suffered by pump barrels when bottom hold-downs are used. One member said types of pump failures should be studied to evaluate the problem properly, especially since, in some instances, wear and abrasion alone are the causes of failure.

No Consensus on Effectiveness

In discussing question 4, some members were of the opinion that one inhibitor will be effective in all wells in one field. Others disagree. One member cited an experience in which three companies used the same inhibitor in wells in the same field and got fairly varied results. Another member said he believed these varied results may have occurred because of difference of well characteristics and rod and tubing loads. He added that variation in results could have resulted from different methods of chemical treatment.

In discussing question 5, one member said he believes the difference in corrosive and non-corrosive sour wells is dependent on the amount of carbon dioxide present. He further was of the opinion that only when carbon dioxide is twice the concentration of hydrogen sulfide will a sour well be corrosive. Another member expressed the view that well corrosiveness could not be determined by acid gas content alone, but some consideration would have to be given to the amount of water produced. The committee expressed considerable interest in this subject and several members agreed to exchange information they had collected.

Predictions Can Be Made

In discussing question 6, one member said that gas and water analysis and percent of producing water could be used to predict corrosion in a sour crude

(Continued on Page 72)

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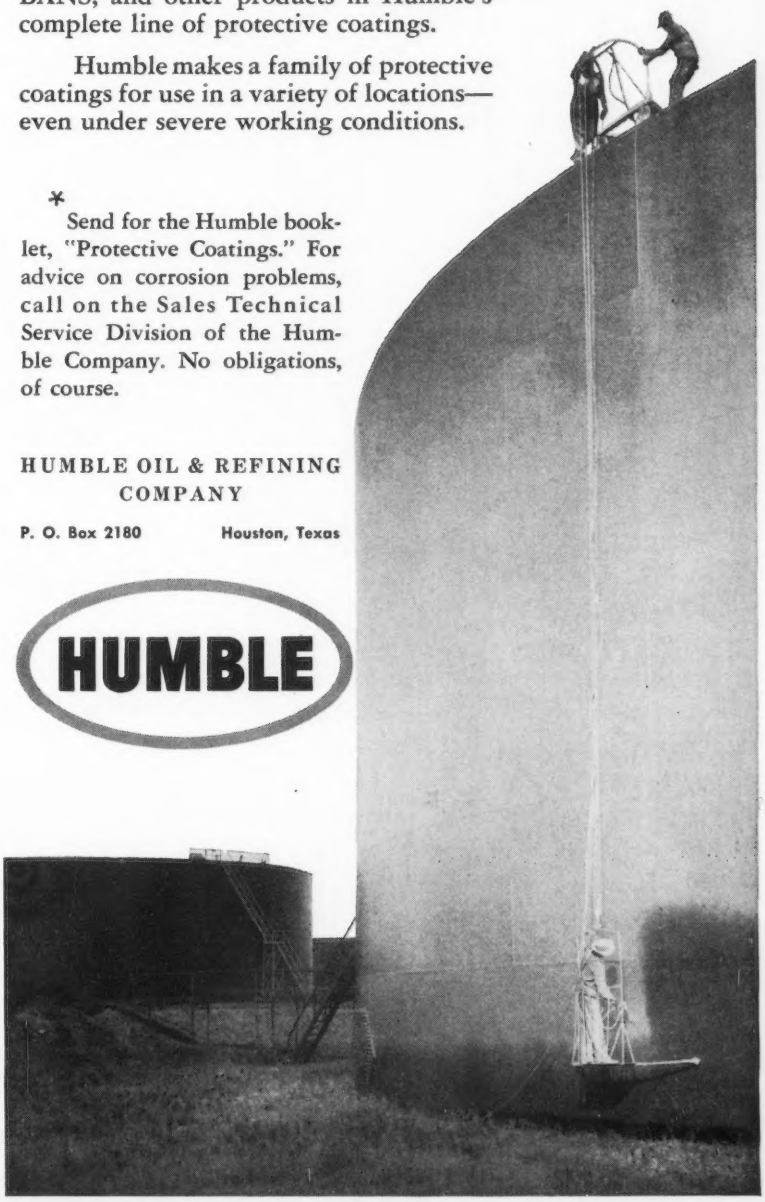

Data to Complete–

(Continued From Page 71)

field. In general, the discussion indicated that at present, operators are relying on examination of failed equipment to determine when corrosion begins in a sour crude field.

In the discussion concerning question 7, it was generally believed an answer has not been reached yet. Oil soluble inhibitors have done good jobs in high water producing wells in which water soluble inhibitors had done poor jobs. However, when these same wells were treated later with water dispersible inhibitors, good inhibition was also obtained. One member said he believed that oil soluble inhibitors should be used when the water cut is high, but there probably would be an upper water cut limit in which the water soluble inhibitors would not be effective.

Although no one had figures to support his belief, it was agreed generally that in regard to question 8, good procedure would be to increase frequency of well treatment as water production increases.

In the discussion concerning question 9, one member said he believed that large diameter casing should be used where internal casing corrosion is a factor and the tubing-casing annulus should be packed off during the well's flowing period. He also thought that equipment should be designed to operate with stresses sufficiently low to allow for anticipated corrosive conditions.

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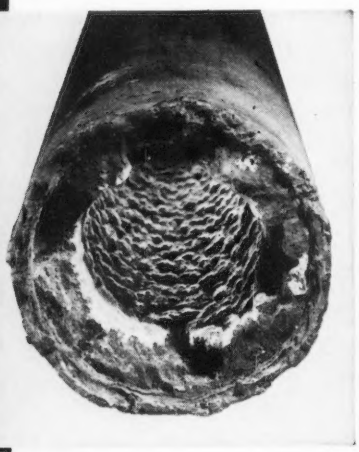

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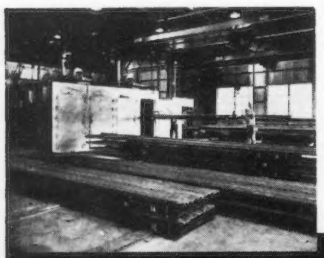

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S. K. Coburn Is Elected Vice-Chairman of Two Technical Unit Committees

S. K. Coburn of the Association of American Railroads in Chicago has been elected vice-chairman of two NACE Technical Unit Committees. In recent elections he was made vice-chairman of Unit Committee T-3A on Corrosion Inhibitors and of Unit Committee T-3C on Annual Losses Due to Corrosion. In addition to his activities on these two committees he is the editor of the Railroad Corrosion News Letter published by NACE Unit Committee T-3E on Railroad Corrosion.

Coburn

Mr. Coburn has a BS from the University of Chicago with a major in organic chemistry and minor in biochemistry. He obtained a master's degree from the Illinois Institute of Technology in organic chemistry on the subject of the Abnormal Reactions of Grignard Reagents with Aldehydes. He worked at the Synthetical Laboratories doing high pressure organic synthesis, at the Miner Laboratories with the Glycerine Producers Association synthesizing derivatives of glycerine and developing new uses for glycerine as well as methods for recovering glycerine from manufacturing processes, developing new methods for synthesizing alkyd resins, and at the Pepsodent Division of Lever Brothers working in the field of protein chemistry, proprietary pharmaceuticals, cosmetics, fats and oil, new product development, corrosion problems and pilot plant development. He is presently employed in the Engineering Division of the Association of American Railroads doing work in the field of non-toxic brine corrosion inhibitors for use in refrigerator cars.

ASTM Copper Strip Corrosion Standards Are Now Available

ASTM Copper Strip Corrosion Standards for use with Method D 130 in determing corrosiveness of automotive gasoline, aircraft engine fuels, farm tractor fuel, cleaners (Stoddard) solvent, Diesel fuel, fuel oil (distillate) and certain other petroleum products are available from American Society for Testing Materials, 1916 Race St., Philadelphia 3. In method D 130 a polished copper strip is immersed at definite temperature for definite time in sample of material being tested. Copper strip is washed, compared and evaluated with Reference ASTM Copper Strip Corrosion Standards.

Standards comprise 13 various colored strips produced by six-color lithograph on aluminum and arranged according to increasing severity of attack. Marginal table lists number and description of reference strips according to Method D 130.

Standards with copy of current Method D 130 are available from ASTM at $25.00 per set.

AND NOW—

Copon

in TRANSCO'S "SUPER INCH"

Long sections of Transcontinental's new 36-inch loop are coated with Copon Internal Pipe Coating for efficient delivery of cleaner gas

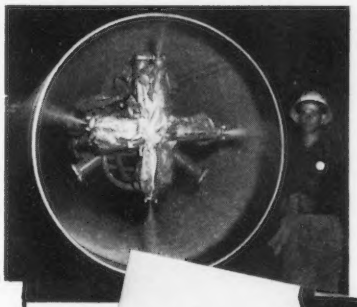
Here are the simple, factual reasons why more and more transmission lines are using COPON:

1. Proven protection against corrosion.
2. Complete internal protection of pipe during stockpiling, transportation and laying of line.
3. Reduced cost of using scrubbers and strainers.
4. Cleaner gas delivery greatly reduces maintenance and labor costs.
5. Over the years COPON saves many times its cost.

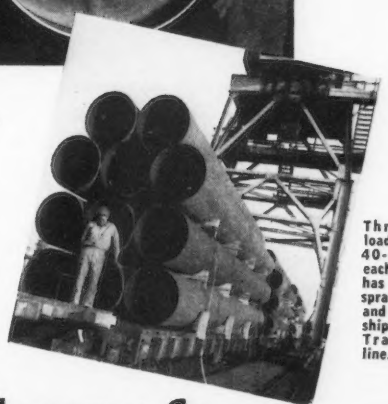
Our technicians can give your corrosion engineers, and others in your company responsible for obtaining most efficient operation, detailed evidence of Copon's exclusive characteristics.

This Coupon is for Your Convenience in Getting More Copon Facts Pronto!

Rows of 36" pipe, destined for Transco's "Super Inch" line, as it is rolled from Consolidated Western Steel Company's Orange plant to Rossen-Richards' yard where it will be chemically cleaned and sprayed internally with Copon, the effective corrosion control coating.



Close-up showing how pipe is pressure-sprayed with Copon at Rossen-Richards yard in Orange, Texas. Pipe is rotated as automatic sprayheads are slowly pulled through entire 40-foot length of pipe.



Three flat cars loaded with eleven 40-foot joints each. This pipe has been Copon-sprayed internally and is ready for shipment to the Transcontinental line.

COAST PAINT & LACQUER CO., INC.
P. O. Box 1113, Houston 1, Texas

Please send me information about COPON Internal Pipe Coating.

Name_____

Company_____

Position or Title_____

Address_____

City_____ State_____

COAST Paint & Lacquer Co. Inc.

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Costanzo

Dial

Larson

Maitland

Munger

Oxford

Philibert

Pierce

Ringer

Skinner

Wade

Wasco

Numerous Technical Unit Committee Officers Are Elected Since Chicago Conference

Unit Committee officers elected at and since the 1955 NACE Conference include the following:

F. W. Schremp, chairman T-1A; California Research Corp., La Habra, California.

Howard Lorenz, vice-chairman T-1A; Standard Oil Co. of California, Taft, California.

D. F. Dial, Jr., chairman T-1M; The Pure Oil Company, Houston, Texas.

T. J. Maitland, chairman T-2B; American Tel. & Tel. Co., New York, New York.

A. W. Jasek, vice-chairman T-2E; Humble Pipe Line Company, Houston, Texas.

O. W. Wade, vice-chairman T-2J; Transcontinental Gas Pipe Line Co., Houston, Texas.

F. E. Costanzo, chairman T-2K; Manufacturers Light & Heat Co., Pittsburgh, Pennsylvania.

J. L. Wasco, chairman T-3A; Dow Chemical Company, Midland, Michigan.

S. K. Coburn, vice-chairman T-3A and T-3C; Association of American Railroads, Chicago, Illinois.

F. W. Ringer, vice-chairman T-3D; Consulting Engineer, Narberth, Pennsylvania.

T. E. Larson, chairman T-4E; Illinois State Water Survey, Urbana, Illinois.

E. N. Skinner, vice-chairman T-5B; International Nickel Co., Inc., New York, New York.

B. J. Philibert, chairman T-5D; Olin Mathieson Chemical Corp., Baltimore, Maryland.

S. W. McIlrath, vice-chairman T-5D; Diamond Alkali Company, Plainesville, Ohio.

Joseph Bigos, vice-chairman T-6R; Steel Structures Painting Council, Pittsburgh, Pennsylvania.

Appointed to the chairmanship of the three odd numbered Technical Group Committees were:

W. F. Oxford, Jr., chairman T-1; Sun Oil Company, Beaumont, Texas.

F. W. Fink, chairman T-3; Battelle Memorial Institute, Columbus, Ohio.

W. G. Ashbaugh, chairman T-5; Carbide & Carbon Chemicals Co., Texas City, Texas.

The even numbered group committee chairmen will change at the 1956 NACE Conference.

Organization of Unit T-6A Is Revised by McFarland

R. McFarland, Jr., Hills-McCanna Co., Chicago, chairman of Unit Committee T-6A has reported a revision in the task group organization of the committee. The following is a list of the task groups and their chairmen:

T-6A-1 Heavy Linings; H. C. Klein, chairman, B. F. Goodrich Co., Cuyahoga Falls, Ohio.

T-6A-2 Vinyl Coatings; K. Tator, chairman, Kenneth Tator Associates, Corapolia, Pa.

T-6A-3 Vinylidene Chloride Polymers; R. L. Brown, chairman, Dow Chemical Co., Midland, Michigan.

T-6A-4 Phenolics; F. Baskett, chairman, Houston, Texas.

T-6A-5 Polyethylene; L. S. Van Delinder, chairman, Carbide & Carbon Chemicals Co., South Charleston, W. Va.

T-6A-6 Rubber and Elastomers; H. C. Klein, chairman, B. F. Goodrich Company, Cuyahoga Falls, Ohio.

T-6A-7 Silicones; R. McFarland, Jr., chairman, Hills-McCanna Company, Chicago, Illinois.

T-6A-8 Methyacrylates; L. S. Van Delinder, chairman.

T-6A-9 Furanes; F. Baskett, chairman.

T-6A-10 Polyesters; R. R. Pierce, chairman, Pennsylvania Salt Mfg. Co., Philadelphia, Pennsylvania.

T-6A-11 Epoxys; C. G. Munger, chairman, Amercoat Corporation, Southgate, California.

T-6A-12 Fluorocarbons; L. A. Ferris, chairman, E. I. DuPont de Nemours & Co., Inc., Wilmington, Delaware.

T-6A-13 Chlorinated Rubber; R. Shankweiler, chairman, Hercules Powder Company, Wilmington, Delaware.

T-6A-14 Rigid Vinyls; C. G. Munger, chairman, Amercoat Corporation, Southgate, California.

T-6A-15 Bituminous Coating; R. Steiner, chairman, Atlas Mineral Products Co., Mertztown, Pennsylvania.

Report to Be Distributed

Drafts of three sections of a proposed Unit Committee T-6K report on Corrosion Resistance Construction with Masonry and Allied Materials were discussed at the committee's meeting in Chicago. Twenty-three members and guests discussed the drafts and decided to rework the report with a revised draft to be sent to members within three months.

Assignments were made for writing additional sections of the report and preliminary drafts are being asked for within three months.

The committee voted to petition that the name of the committee be changed to Chemical Resistant Masonry Construction, a title the committee feels is more descriptive of the work currently underway.

T-2C-1 Is Reorganized

L. P. Sudrabin, Electro Rust-Proofing Corp., Newark, N. J., chairman of Unit Committee T-2C on Minimum Current Requirements for Cathodic Protection has reported the reorganization of Task Group T-2C-1. The task group is assigned the specific problem of preparing tentative specifications for measuring minimum current requirements for cathodic protection of pipelines. The name of the Task Group is Criteria for Cathodic Protection.

Corrosion handcuffed in alcohol-acid plant. These valves of "HASTELLOY" high nickel-base alloy assure the desired uninterrupted operation between inspections. Produced by Hasco Valve and Machine Co., Milwaukee, Wisc.

Nickel-base alloy stops unscheduled shutdowns

. . . handles 50-60% H_2SO_4 at 200-250°F

Meet some valves that show exceptional corrosion-resistance. They are made of HASTELLOY alloy D, a high nickel-base alloy.

A large oil refinery installed these valves in plants that process and concentrate sulphuric acid, which, in turn, is used for producing isopropyl and ethyl alcohol and ethers.

And here's what this user writes:

"At present, the units are on a four-month scheduled inspection and repair interval. HASTELLOY *alloy D fittings are the only ones available that do not require unscheduled shut downs for replacement and accompanying loss of production between these inspections.*

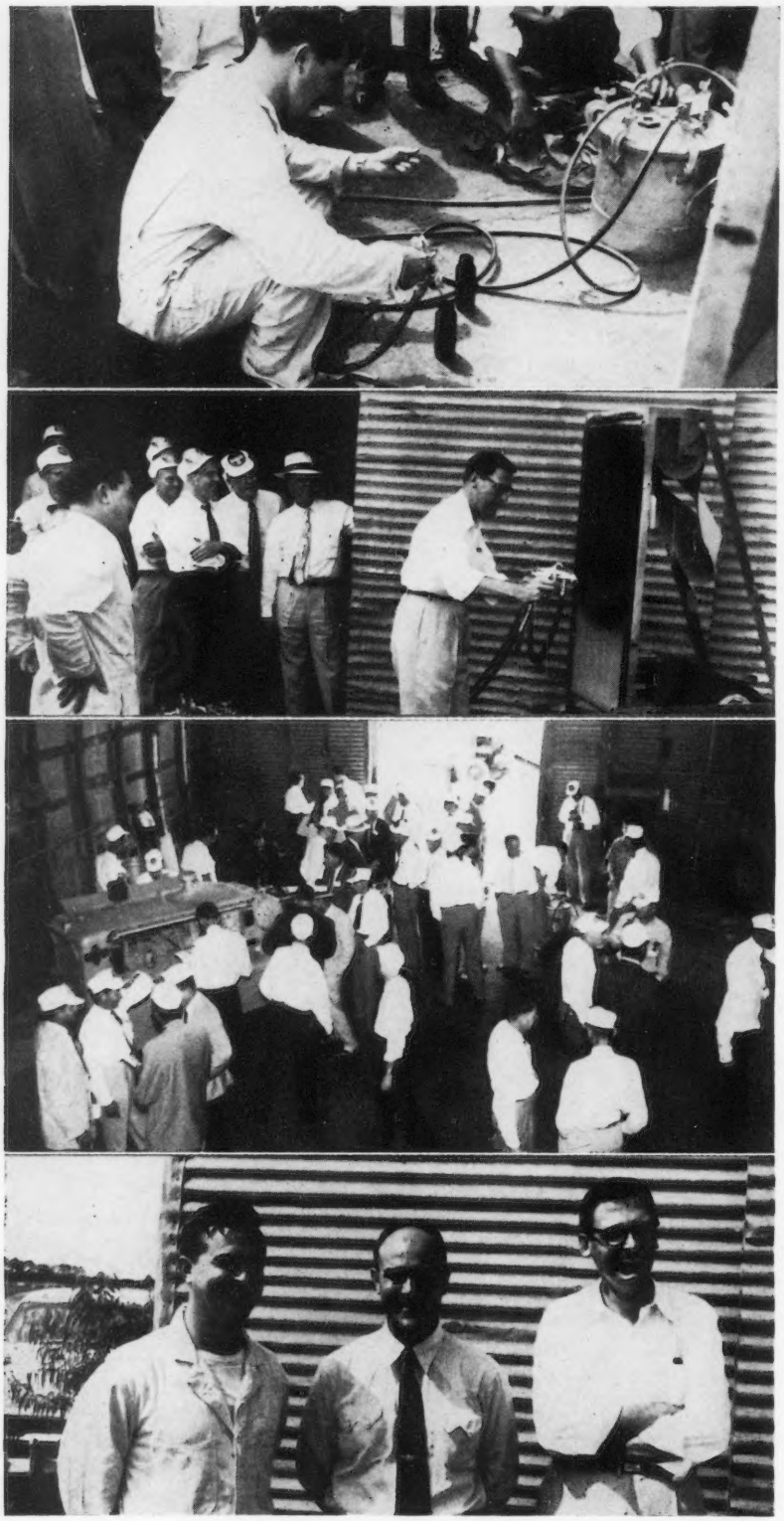
Scores of users report similar savings where equipment is exposed to strong corrosives.

You, too, may obtain excellent results by using one of the series of nickel-base alloys produced and sold under the trade-mark "HASTELLOY" by Haynes Stellite Company, Kokomo, Indiana, a Division of Union Carbide and Carbon Corporation.

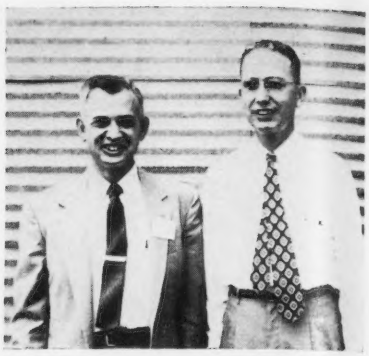
Whatever your corrosion difficulty, make use of our wide practical experience. Send details of your problem for our suggestions. Write us today.

INCO TRADE MARK

THE INTERNATIONAL NICKEL COMPANY, INC. 67 Wall Street New York 5, N. Y.



SEEN AT THE T-1M SHORT COURSE—Top, J. E. Rench, Jr., Napko Paint and Varnish Works, Houston, demonstrates method of calibrating flow of paint from spray gun. Second, Sidney V. Smith, Napko, demonstrates correct method of handling gun in spray painting. Third, group inspecting display of sandblasting equipment, air compressors, thickness gauges. Bottom, left to right, J. E. Rench, Jr., E. W. Oakes, Clemtex, Inc., Houston, and S. V. Smith, Nakpo, who were active in organizing the course.



OFFICERS OF T-1M, left, F. E. Blount, Magnolia Petroleum Co., Dallas, vice-chairman, and D. F. Dial, Jr., Pure Oil Co., Houston, chairman.

One-Day Painting Application Course Held by Unit T-1M

Protective Coating Application was the subject of a short course sponsored by NACE Technical Unit Committee T-1M on Corrosion of Oil and Gas Well Producing Equipment in Offshore Installations on May 12. More than 80 attended the short course held at the Golfcrest Country Club in Houston, Texas. The short course was arranged and presented by representatives of Napko Paint & Varnish Works of Houston. Instrumental in making arrangements for the short course were D. F. Dial, Jr., Pure Oil Company, chairman of T-1M and Sidney V. Smith, Napko Paint & Varnish Works from Houston.

In opening the short course, Chairman Dial told the group that offshore corrosion and its mitigation is a major cost factor of any operator exploring drilling and producing on the continental shelf. The increasing investment in marine equipment and offshore structures with the cost involved are of major concern to all operators. He said that a conservative estimate would be $4,000,000 or more was spent in 1954 by offshore operators as a direct cost of mitigating corrosion, with no allowance for deterioration. Most of this money was spent on protective coatings and application. Maintenance cost on some offshore drilling platforms may be as high as 30 cents per square foot or more per year. Also some of the shipyard costs run this much or more on marine vessels.

Hope to Reduce Costs

Mr. Dial added that with some effort, education and persistent specifications, the committee feels this cost can be reduced two-thirds or more. He explained that offshore drilling and producing equipment requires better paints and application techniques than have been used in the past. Advances in chemistry and physics have made organic and non-organic coatings available that were unknown ten years ago. These new materials are not cure-alls but have proved far superior to conventional paints if certain conditions are fulfilled.

Mr. Dial told the group the committee is working on detailed standard specifications which will refer often to sur-

(Continued on Page 78)

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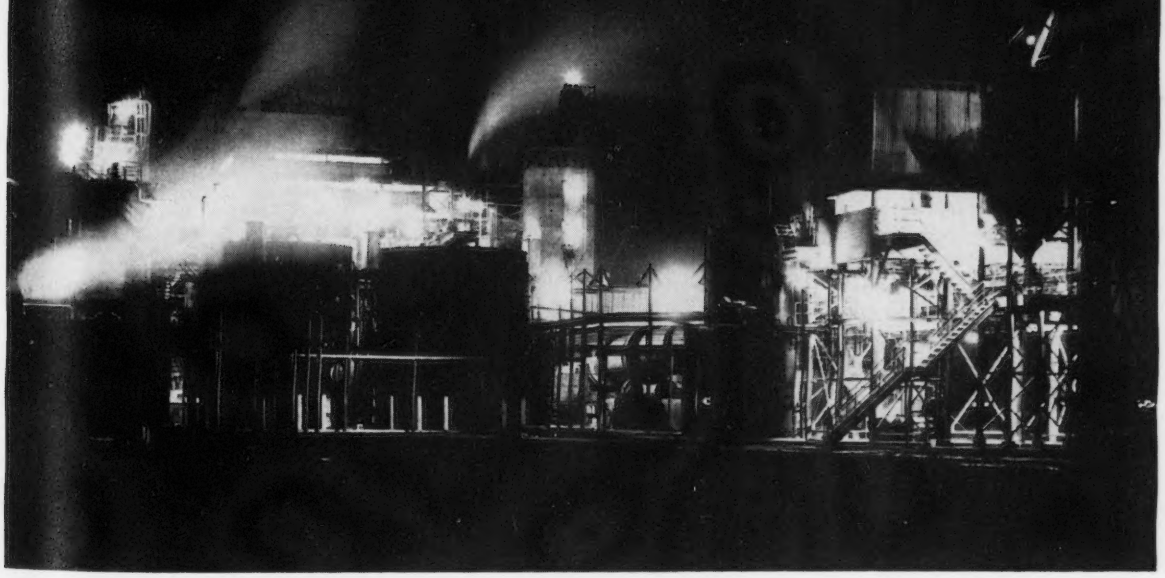
PROTECTIVE COATINGS
. . . the tough skin of industry

We can show you INSUL-MASTIC Coatings that have been preventing corrosion for 10, 12 and 15 years. Many of these applications are in industrial plants where corrosive fumes and vapors have been known to eat through other coatings within a very short time.

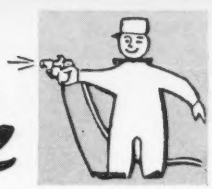
These INSUL-MASTIC Coatings have lasted through these many years without need of replacement.

This is an exceptional record. It should be considered seriously when you specify Protective Coatings.

It pays to think first of the coatings that last . . . INSUL-MASTIC.



Insul-Mastic



think first of the coatings that last!

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You can solve your tough corrosion problems by using Bitumastic® Coatings

INDUSTRIAL ATMOSPHERES test the effectiveness of any protective coating. Bitumastic® Super-Service Black does an excellent job of protecting this structural steel. Crevices and corners that are hard to seal with ordinary paints are easily and thoroughly protected by this heavy-duty coating.

TOUGH CORROSION problems *can* be solved, but not by using ordinary maintenance paints or conventional protective coatings. For long-term protection, it takes *specialized* Bitumastic Protective Coatings—the kind that Koppers makes.

Bitumastic Protective Coatings are specially formulated from a tar pitch base* that is, for all practical purposes, impervious to moisture. These coatings keep moisture away from exposed metal surfaces . . . and that's the *best* way to stop corrosion.

Bitumastic Coatings are also extra-tough and extra-thick. Where other factors are equal, the *thicker* the coating the *longer* the period of protection.

Send for a set of free booklets describing the family of Bitumastic Protective Coatings. At the same time, tell us about *your* corrosion problem so that we can suggest a satisfactory solution. You incur no obligation, of course.

*Hi-Heat Gray is a non-coal-tar vehicle with metallic pigment

KOPPERS COMPANY, INC.

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KOPPERS®

One Day Painting–

(Continued From Page 76)

face preparation specifications of NACE Unit Committee T-6G and to Steel Structures Painting Council's specifications. He explained the committee's aim to make it possible for all to know what is desired so bids can be made on a rational basis.

In arranging the short course, the committee invited representatives of suppliers of protective coatings, shipyards and applicators' contractors. General theme was that correct application is of vital importance in cutting down maintenance cost on offshore equipment.

Surface Preparation Stressed

Ed Oakes of Clemtex Corporation of Houston, explained the necessity for good surface preparation and described necessary sand blasting equipment and techniques. Mr. Oakes said that in sand blasting, employing competent personnel is of utmost importance. In descending order of importance in sand blasting are: hardness of grit, air pressure, length of nozzle and attitude of nozzle in relation to material being sand blasted. Mr. Oakes told the group that air is the most expensive item used in sand blasting and described in detail how to choose correct equipment and air pressure for a given job.

Correct Method Demonstrated

Joe Rench of Napko Paint & Varnish Works described at length the correct way to spray on protective coatings. The group saw a 50-minute film on the correct use of paint spraying equipment after Mr. Rench completed his talk.

Napko Paint & Varnish Works were host at lunch for the group. After lunch, demonstrations were given on sand blasting, paint spraying and use of coating inspection instruments. Everyone attending had the opportunity to actually use the equipment to spray paint and to use the film thickness inspection instruments.

Following the short course, committee T-1M held a short business meeting. Three task groups and task group chairmen were assigned to pursue the committee's objectives. The task groups set up and chairmen assigned are: Protective Barriers, H. E. Waldrip, Gulf Oil Corporation, chairman; Cathodic Protection, W. H. Edwards, Superior Oil Company, chairman and Design Considerations, E. R. Stauffer, Humble Oil & Refining Company, chairman.

The committee decided to try to arrange a symposium to be presented at the South Central Region meeting in Houston in October of this year.

Cathodic Protection Overlay Map Planned at Chicago

An overlay map showing cathodically protected underground structures in Chicago is the proposed activity of Chicago Section's Committee on Cathodic Protection of Underground Structures. Initial aim of the committee is to serve as a clearing house for information on foreign bonding and other information about systems now in use or installed in the future.

NACE News

Schedule Completed for Washington U. Course

LEADERS IN EAST TENNESSEE SECTION'S April 12 session at Knoxville on sulfuric and nitric acid corrosion problems were, left to right: J. L. English, Oak Ridge National Laboratories, section chairman; D. B. Stone, The Duriron Co., Knoxville, chairman of the program committee; R. E. Williams, Tennessee Eastman Corp., speaker; F. Kertesz, Oak Ridge National Laboratory, section secretary.

Corrosion Problems Allied With Sulfuric, Nitric Acid Wastes Discussed at Knoxville

Plant Corrosion Problems on Sulfuric and Nitric Acids was the topic of a discussion April 12 at Knoxville, Tenn. during a meeting of East Tennessee Section. Robert A. Williams of Tennessee Eastmen Company, Kingsport was the speaker. D. B. Stone, The Duriron Co., Knoxville, was technical program chairman.

Mr. Williams first described materials and methods used in handling various strengths of sulfuric acid in the concentration units and told of some problems solved in his experience. Nitric acid concentration units, using sulfuric acid as the concentration agent were described with particular reference to materials and operating experience. The new process of using magnesium nitrate instead of sulfuric acid to concentrate nitric acid was described with the changes it brought in corrosion prevention. Its simplicity and low cost versus the sulfuric acid process were explained.

Use of sonic measurements of vessel thickness has made it possible to keep equipment in use for extended periods, Mr. Williams said.

Short Course on Corrosion Problems in Process Industries Is Scheduled

A tentative program has been completed for the November 14-16 Short Course on Corrosion Problems in the Process Industries at San Francisco, Cal. The course is to be given at the University of California at Berkeley during the three days preceding the November 17-18 Western Regional Division meeting at San Francisco.

Monday, November 14

Registration and equipment inspection in process plants, corrosion testing in process plants, handling sulfuric acid, caustics.

Tuesday, November 15

Furnace stack corrosion, high temperature problems in process plants, special metallurgical problems including stress corrosion, graphitization and hydrogen attack.

Wednesday, November 16

Cooling water problems, inhibitors in process plants, linings for corrosion protection (with emphasis on lining existing equipment), cathodic protection in the process industries.

Illinois U. Short Course

The Second Short Course on Cathodic Protection will be held December 5-9 inclusive at the University of Illinois, Urbana.

Northeast Region Meeting Features Panel Conference

A panel Conference on Underground Corrosion is scheduled to be a feature of the November 1-3 Northeast Region meeting at Niagara Falls, N.Y. Facilities have been reserved also at the headquarters Hotel Niagara on October 31 for meetings of technical committees.

St. Louis Section Is Cooperating in 5-Day September 12-16 Event

The schedule for the September 12-16 Washington University, St. Louis Short Course on Corrosion has been completed. Greater St. Louis Section NACE is cooperating with the university in presenting the course.

Monday, September 12

9 am-12—Corrosion Theory, Reactions, Factors and Fundamental Mechanisms. L. E. Stout (or alternate) Head, Dept. of Chemical Engineering, Washington University.

2-5 pm—Metallurgical and Mechanical Factors Affecting Corrosion by Julius J. Harwood, Head, Metallurgy Branch, Office of Naval Research, Dept. of the Navy, Washington, D.C.

Tuesday, September 13

9 am-12—Types of Corrosion; Diagnosis and Treatment of Corrosion difficulties, Including Designing to Prevent Corrosion by M. G. Fontana, Chairman, Dept. of Metallurgical Engineering, Ohio State University, Columbus.

2-5 pm—Treatment of Environment; Chemical Methods, Selection and Behavior by Norman Hackerman, Professor of Chemistry, University of Texas, Austin.

Wednesday, September 14

9 am-12—Selection of Materials of Construction in Particular Environments by Emil G. Holmberg, Chief Metallurgist, Alloy Steel Products Co., Linden, N.J.

2-5 pm—Corrosion Testing Methods and Evaluation by Aaron Wachter, Head of Materials Engineering and Corrosion Department, Shell Development Co., Emeryville, Cal.

Thursday, September 15

9 am-12—Cathodic Protection: Theory and Measurement by L. P. Sudrabin, Director of Engineering Service and Development, Electro Rust-Proofing Corp., Belleville, N.J.

2-5 pm—Cathodic Protection: Practical Application and Economics by A. W. Peabody, Ebasco Service, Inc., New York.

Friday, September 16

9 am-12—Protective Coatings. Surface Preparation, Application and Behavior by Arno J. Liebman, Pitmar Corp., Baltimore, Md.

2-5 pm—Protective Coatings: Metallic and Organic — Fundamentals and Selection by Walter B. Meyer, President, St. Louis Metallizing Co., St. Louis, Mo.

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Of the 98 articles published in Corrosion's Technical Section during 1954, all but seven were original material.

Permian Basin Lays Plans for Corrosion Tour To Be Held During September or October

Plans to hold the Sixth Biennial Permian Basin Corrosion Tour during September or October were approved at an April 11 meeting of Permian Basin Section. Previous tours were held in 1949, 1951 and 1953.

Chairmen of committees were named as follows:

Exhibits—John C. Watts, Internal Pipeline Maintenance Co., Odessa.

Tour Secretary and Tour Report—A. A. Alberts.

Publicity—Tom Matthews.

Registration—E. O. Kemper, Permian Enterprises, Inc., Odessa.

Transportation—C. C. Michel, Cardinal Chemicals, Inc., Odessa.

Entertainment—Fred W. Gipson, Continental Oil Co., Midland.

Charles W. Elwell of the Western Co., Midland, spoke on "The Anomaly of Being an Engineer" to approximately 55 members and guests.

It was decided also to hold meetings through the summer.

Gasoline Plant Corrosion Is Houston June 14 Topic

Technical subject for the June 14 meeting of the Houston Section will be Gasoline Plant Corrosion by D. R. Fincher, Tidewater Associated Oil Co., Weimer, Tex. There will be no July Section meeting.

Barbecue, golf and dancing crowded out more technical subjects at the May 10 annual picnic and recreation meeting of the Houston Section. The outing was held at the Texaco Country Club. Their appetites whetted by strenuous exertion, 139 Section members and guests ate 175 pounds of barbecue, 45 pounds of potato salad and 30 pounds of beans. Other games played were croquet, badminton, horseshoe pitching and table tennis.

Tied for first place in the golf handicap tourney were Jean Wood, Haynes-Stellite Co. and Bob Huff, NACE Central Office with scores of 67. F. W. Gartner, Jr., F. W. Gartner Co. was second with 68. John Wood, Aquaness Corp., Bill Wood, Products Research Service, Inc. and R. A. McCarthy, Hill, Hubbell & Co., Division of General Paint Corp., tied for third place with 69. The driving contest was won by Bob Huff with 290 yards. The "Closest to the hole contest" was won by G. L. Garwood, Phillips Petroleum Co.

High Temperature Corrosion

E. C. Winegartner, Humble Oil & Refining Co. presented a talk on Alloy Steels In High Temperature Service during the April 12 meeting of the NACE Houston Section which was held in Houston. Mr. Winegartner discussed limitations of present alloys with respect to ductility and long time stability at temperatures above 900 F for 50,000 hours or more. He provided information on effect of various alloying elements on structure and stability of stainless steels as well as data on more common austenitic and ferritic stainless steels.

Projector Is Purchased

Slides that are obscure or blurred as the result of poor projection, the bane of many a technical speaker, will plague few speaker's at Houston Section technical meetings. The Section has bought a new slide projector which, even with the room lights on, throws a sharp, large image on the screen with excellent definition. The projector was used for the first time at the April 12 meeting.

The committee selecting the slide projector was composed of George Hall, Thornhill-Craver Co., Inc.; Joy T. Payton, The Texas Co. and Jack Davis, Cathodic Protection Service.

Role of Water Consultant Is Alamo Section's Topic

J. B. Gibson of D. W. Haering & Company, Inc., presented a paper on "The Role of a Water Consultant in Corrosion Mitigation," at the April 26 meeting of Alamo Section.

Mr. Gibson's talk was a general educational discussion of the factors involved in waterside corrosion of industrial water-using equipment. He covered the basic chemical reactions of the electrochemical theory involved and pointed out the three problems confronting the consultant, these being: scale, microorganisms and corrosion. Mr. Gibson stated that the concentration of the electrolyte in the presence of heat-flow energized metals as encountered in industrial water systems introduce many variables and rate factors not encountered in other applications, which causes the problems to become more complicated especially in the case of the electrolyte performing multiple services. He said basic consideration must therefore be given to the conditions existing at the water-metal interface as influenced by velocity, skin temperature, temperature gradients and inclusions.

In addition to discussing the common forms of attack and conventional methods of control, Mr. Gibson stated that each problem must be studied to determine the major factors which would be encountered and correlation of analytical inspection and operational data is continuously required for assurance of control.

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A tabular topical index of the contents of the Corrosion Abstract Section of Corrosion is published annually in December.

Corpus Christi Section

Approximately 25 members and guests of the Corpus Christi Section heard Bill Moore of Reynolds Metal Company speak April 26 on The Established Applications of Aluminum in Process Industries.

It was announced that meetings for the remainder of the year will be held on the fourth Tuesday monthly.

Sabine-Neches Section

Twenty-five members and guests of Sabine-Neches Section saw a film on "The Science of Making Brass" at the April 28 meeting.

Next meeting of the section, the last of the season, is scheduled May 26 at the Little Mexican Restaurant in Orange, Texas.

NATIONAL, REGIONAL MEETINGS and SHORT COURSES

1955

Oct. 18-21—South Central Region, Shamrock Hotel, Houston

Nov.

1-3 Northeast Region meeting. Hotel Niagara, Niagara Falls, N. Y.

Nov. 17-18—Western Region, Sir Francis Drake Hotel, San Francisco, California

1956

Mar. 12-16—NACE International Corrosion Conference and Corrosion Show, Statler Hotel, New York, New York

Oct. 2-5—South Central Region, Beaumont, Texas

1957

Mar. 11-15—NACE Annual Conference, Kiel Auditorium, St. Louis, Missouri

1958

Mar. 17-21—NACE Annual Conference, Civic Auditorium, San Francisco, California

1959

NACE Annual Conference, Sherman Hotel, Chicago, Illinois.

SHORT COURSES

1955

Sept. 12-16—Washington University, St. Louis.

November—University of California—NACE Western Region. Process Industries.

Dec. 5-9—University of Illinois, Urbana.

NACE MEETINGS CALENDAR

June

Niagara Frontier. Social Meeting—Ladies Night.

June

28 Corpus Christi Section.

Nominations for 1955 NACE Awards

Nominations of persons to receive the Whitney or Speller Awards, accompanied by statements showing the basis of the nominations should be sent to Regional Chairmen before July 1. Nominations may be made by Sections or by individual members.

Tank Painting Covered at New Orleans-Baton Rouge Section Meeting April 25

W. H. Baker of Shell Oil Company, Narco, Louisiana, spoke on tank painting practices at Shell's Narco Refinery at the April 25 meeting of the New Orleans-Baton Rouge Section. Mr. Baker's talk covered practices followed during the Narco refinery expansion involving 29 tanks, 17 floating roof and 12 cone roof types ranging in size from 170 feet in diameter down to 50 feet and having a total combined surface area of approximately 750,000 square feet.

A new type tank scaffolding, relative merits of shop pickled and primed tank steel vs. field sand blasting of both new and old tank steel and proper field handling of the weld areas were major subjects of Mr. Baker's talk. Cost studies of the job indicated a 4-5% cost advantage for the pickled and primed steel on the average, even though the weld areas required sand blasting and field priming. A complete breakdown of cost figures were presented which developed a lively discussion among the 19 members and guests attending the meeting.

The next meeting of the New Orleans-Baton Rouge Section was scheduled May 23 to consist of a panel discussion on Cathodic Protection of Flow Lines and Gathering Lines.

More Data Are Given on April Cover Photograph

Because of the wide interest in the circumstances leading to the perforation of the cast iron water main pictured on the front cover of April, 1955 Corrosion, the following additional information supplied by Hugh L. Hamilton of A. V. Smith Engineering Company, Narberth, Pa. is provided:

"The damaged piece of 8-inch cast iron pipe was located approximately 500 feet from a 600-volt DC railway substation in which the main short circuit occurred. A steel culvert crossed the water main at right angles and was approximately one inch distant. The water main was part of a large distribution system. The culvert was approximately 50 feet long and was not connected to any other structure or to the substation.

"The fault caused large currents to flow to the fault from the two adjoining substations supplying the same railway system. To the best of our knowledge these fault currents continued for approximately 60 cycles. The earth currents established by this fault resulted in an abnormal voltage gradient between the water main and the culvert, causing an arc.

"It is difficult to estimate the amount of short-circuit current which flowed, but it was probably in the order of magnitude of 2000 amperes. As can be seen by the picture, a penetration of the water main resulted. The drainage culvert, incidentally, had a hole approximately six inches in diameter. Of course the culvert is of a considerably lighter gauge metal than the cast iron."

Greater Boston Section

Greater Boston Section was scheduled to hear Robert C. Hedlund of Dow-Corning Corporation speak on Silicones in Heat and Corrosion-Resistant Coatings at the May 17 meeting.

Flournoy, Janota and Kalhauge Elected at Chicago

R. W. Flournoy, Corn Products Refining Co., Argo, Ill. was elected chairman; R. B. Janota, Swift & Co., Chicago, vice-chairman; V. M. Kalhauge, Standard Oil Co. (Indiana), Chicago, secretary and W. A. Watkins, The Duriron Co., Inc., Chicago treasurer by Chicago Section January 15.

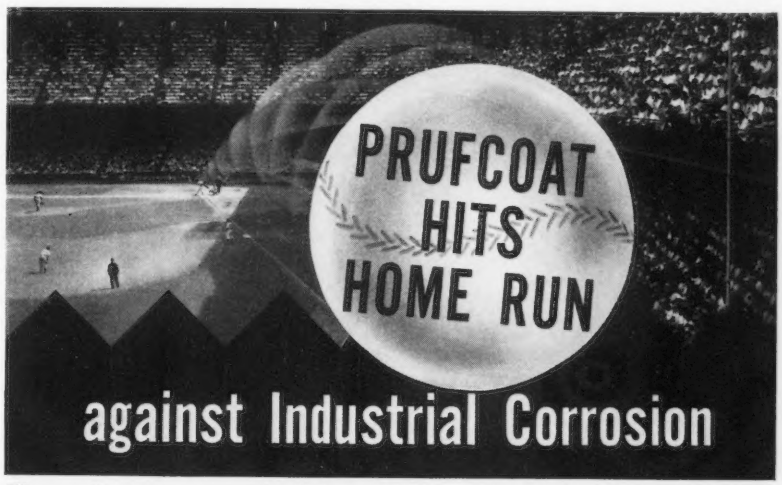
About 70 members and guests saw the motion pictures, "Must It Rust?" loaned by Fred Brightly, Jr., of Brightly Galvanized Products Co., Inc. and "The Big Crossing" loaned by Jack Byrd, General manager of Lakehead Pipeline Company. The first picture concerned technical and practical aspects of hot dip galvanizing. B. J. Barmack, Commonwealth Edison Co., talked briefly and answered questions about hot dip galvanizing.

The other film showed in color the details of laying the pipeline across the straits of Mackinac, said to be the world's deepest pipeline crossing.

The annual corrosion round table was scheduled for the May meeting.

Central Arizona Section

R. J. Emerson, El Paso Natural Gas Co. was the scheduled speaker for a May 18 meeting of Central Arizona Section. His topic was Cathodic Protection Practices as Applied to Pipe Lines.



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3 **PRUFCOAT New Fast-Dry Primer P-50 Lets You Over-Coat In Just Two Hours!**

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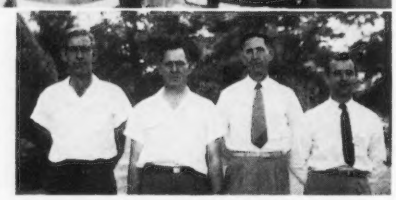

SHREVEPORT SHORT COURSE—(Top) Instructors at the May 5-6 Shreveport Section—Centenary College Fifth Annual Corrosion Control Short Course, left to right, back row: Lynton B. Irish, Irish Engineering Co.; George W. Wafer, Arkansas-Louisiana Gas Co.; M. J. Olive, Arkansas Fuel Oil Corp.; John J. Wise, Arkansas-Louisiana Gas Co.; Lionel B. Morrow, Interstate Oil Pipeline Co.; front row: William F. Levert, United Gas Pipe Line Co.; Ned C. Stearns, D. E. Stearns Co.; James M. Steele, United Gas Pipe Line Co.; D. D. Hansen, Universal Polychem Co. (middle) John Wise addresses registrants. (bottom) Group at lunch at Centenary cafeteria. (side) Shreveport Section members responsible for course: Joseph D. Bland, Triangle Pipe Line Co., section treasurer; Raymond C. Jordan, United Gas Pipe Line Co., section chairman; C. W. Evans, United Gas Pipe Line Co., general chairman of the short course; Gaston V. Jones, Arkansas-Louisiana Gas Co., section vice-chairman.

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Prospective authors of technical papers intended for publication in Corrosion are invited to write for copies of the NACE Guide for Preparation and Presentation of Papers.

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Besides magazines in the United States, articles or digests of articles in Corrosion have been published in periodicals in Belgium, England, France, Germany and Japan.

Two-Day Shreveport Short Course Attracts 150 Persons

Approximately 150 persons registered for the May 5-6 Fifth Annual Corrosion Short Course of Shreveport Section and Centenary College, Shreveport. Sessions were held in the auditorium of the science building on the college campus.

A program covering the fundamentals of corrosion designed for superintendents, foremen, field men and engineers not regularly engaged in corrosion work was presented. C. W. Evans, United Gas Pipe Line Co. was general chairman and W. F. Levert, United Gas Pipe Line Co. was program chairman.

Long Discussion Follows Talks at San Francisco

A 45-minute discussion period followed the presentation of three corrosion problems and their solutions at a April 27 meeting of San Francisco Bay Area Section. About 32 members attended.

Talks were made by Bill Colman on sulfuric acid recovery problems; George J. Puckett, Dow Chemical Company, Pittsburgh, Cal. on stress corrosion in caustic solutions and by George A. Works, Union Oil Company of California, Rodeo, Cal. on cathodic protection in heat exchangers.

Peabody Talks at Montreal

A general meeting of Montreal Section was held at the Queen's Hotel in Montreal April 19. The 17 members attending heard A. W. Peabody of Ebasco Services, New York, speak on Corrosion Problems in Plant Design.

It was announced that a new secretary-treasurer, M. D. Phillips, had been elected to replace E. P. Hersey. Mr. Phillips is associated with McColl-Frontenac Oil Company, Limited, in Montreal.

Western Region Officer

T. J. Smith of the Electric Steel Foundry Company, Emeryville, California, has been appointed secretary-treasurer of the Western Region to fill the vacancy created by the resignation of E. F. Hensley.

North Texas Section Social

The annual social meeting of the North Texas Section was held at White Rock Lake, Dallas, Texas the evening of May 6. Thirty-one members, wives and 25 children attended the meeting which will be the last of the current season until September 12.

Ken Robbins of Otis Pressure Control, Inc., won the washer pitching contest.

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More than 5000 copies of Corrosion published during 1954 were mailed from Central Office NACE. These were in addition to the regular monthly mailings of the magazine.

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Five Members Added to Editorial Review Group

Five members have been added to the NACE Editorial Review Sub-Committee, bringing the number to eleven, including the chairman, A. W. Tracy, American Brass Co., Bridgeport, Conn. This is the largest number ever to be on this committee and a consequence of the increased volume of technical material being submitted for publication.

Papers have been submitted for publication in Corrosion in recent months from New Zealand, Australia, Israel, Egypt, and France, besides those originating in the United States and Canada.

New members added are: Franklin H. Beck, Engineering Experiment Station, Ohio State University, Columbus; Jerome Green, National Aluminate Corp., Chicago; Harry J. Keeling, Consultant, Los Angeles; E. V. Kunkel, Celanese Corp., Bishop, Texas; E. N. Skinner, The International Nickel Co., Inc., New York.

Discussion Policy Change

Beginning with the June issue of CORROSION, discussions of technical articles, when they do not appear immediately after the articles to which they pertain, will appear only in the June and December issues. It has been the practice heretofore to publish discussions whenever approved when they were not appended to their related article.

Discussions to technical articles published in the interval January-June will appear in the June issue and discussions to articles published in the interval July-December will appear in the December issue.

Existing policy will not be changed with respect to submission of discussions. Discussions of articles submitted without invitation will be considered for publication at any time.

Color Inserts Will Be Accepted in Corrosion

Effective with the issue of January, 1956 or sooner if rates and specifications can be prepared, advertisements consisting of preprinted color inserts will be accepted for inclusion in Corrosion immediately preceding the inside back cover. Inserts will not be included in Corrosion at any other location and the right to limit the number of inserts in any one issue is reserved.

Plans contemplate acceptance of single and double page preprints and four-page inserts with various combinations of preprinted pages. Rates will be comparable to others charged by publications of approximately the same characteristics as Corrosion.

Distribution of rates and specification data will be made automatically to all current advertisers and others on the publication's prospect mailing lists. Interested companies may get additional copies on request.

Tear Sheet Copies to Be Given to Technical Authors

Beginning with an early issue of Corrosion and in any case not later than the July, 1955 issue each author of a paper printed in the Technical Section will be sent gratis 25 tear sheet copies of his article. This distribution will take the place of the current practice of sending to each author 5 copies of the issue in which his article appears.

The change was authorized by the NACE board of directors at Chicago on recommendation of the Publication Committee. Many authors wanting a few additional copies of their articles found the association's reprint prices and alternates unacceptable.

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More than 5000 copies of Corrosion published during 1954 were mailed from Central Office NACE. These were in addition to the regular monthly mailings of the magazine.

Use "CORECO" Corrosion Rectifiers . . .
Designed to Give the Best Results

"CORECO" systems of corrosion rectification give your pipe lines and storage tank bottoms, offshore lines and marine installations better protection through better engineering.

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BOOK REVIEWS

Protective Coatings for Metals. By R. M. Burns and W. W. Bradley. Second Edition. 1955. 643 pages, 6 x 9 inches, cloth. Reinhold Publishing Corp., 430 Park Ave., New York 22, N. Y. Per copy $12.

This book, which has been thoroughly revised to include developments in coatings during the fifteen years since publication of the first edition, is intended principally for the person who uses coatings to protect metals. Information relative to formulation is included where needed to clarify applicatory problems. In both foreword and preface substantial notice is taken of the urgent need to preserve metal resources by limiting corrosion.

The first chapter is devoted to principles of corrosion and corrosion control, describing how metals react with their environment and how these reactions may be controlled. Comprehensive discussions on surface preparation, types of metallic coatings, sprayed metal coatings, production and properties of zinc coatings, protective values of zinc coatings and cadmium coatings and their protective value follow.

Additional chapters follow on coatings of copper, lead and other metals and alloys, noble metals, methods of testing, organic coatings, application and use of organic coatings, chemical conversion and anodized coatings, special purpose coatings and corrosion inhibitors.

Each chapter is liberally referenced and there is an author index and comprehensive alphabetical subject index.

What Every Engineer Should Know About Rubber. By W. J. S. Haunton. 128 pages, 5½x8½ inches. 1954. British Rubber Development Board, Market Buildings, Mark Lane, E. C. 3, England. Availability not indicated.

This book discusses the agricultural aspects of rubber, engineering applications, properties, rubber technology, uses of rubber in engineering, and under a heading "Resistance to Corrosion and Chemical Attack," says in part "The outstanding resistance of rubber, which is a hydrocarbon (and therefore chemically inert) to attack by chemicals other than solvents, oxidizing and halogenating agents, has led to its wide use in lining chemical plant." Details of uses in lining vessels are given. There is an alphabetical subject index.

Surface Coating Resin Index, 6 x 9 inches, 52-pages, paper. February 1955. The British Plastics Federation, 47, Piccadilly, London, W.1. and Surface Coating Synthetic Resin Manufacturers Assn., 79-80, High Holborn, London, WC.1. Per copy 3 Shillings (post free).

First comprehensive index of all British-made surface coating resins available to paint, printing ink and allied trades. So far as complex chemical nature will permit, 733 resins are classified according to type and within each of 14 classifications (entered on as many tables) they are listed alphabetically by trade name. A list of contributing producers and indexes to producers and trade names are included.

HON. ROBERT F. WAGNER, mayor of the city of New York is shown addressing members of the Northeast Region May 10 at Hotel Statler, New York. The May 9-11 meeting attracted 300 registrants.

8 States Adopt Industrial Waste Control Policies

Adoption of an industrial-waste control policy by Illinois, Indiana, Kentucky, New York, Ohio, Pennsylvania, Virginia and West Virginia is reported by the Ohio River Valley Water Sanitation Commission, 414 Walnut St., Cincinnati 2. Policy provides that requirements for modification or restriction of industrial-waste discharges will be designed to safeguard and maintain water uses that will serve the public interest in the most beneficial and reasonable manner, the commission explained. It said restrictions spell out a statutory provision in the Ohio River Valley interstate compact that all waters are to be free from unsightly or malodorous nuisances due to floating solids or sludge deposits.

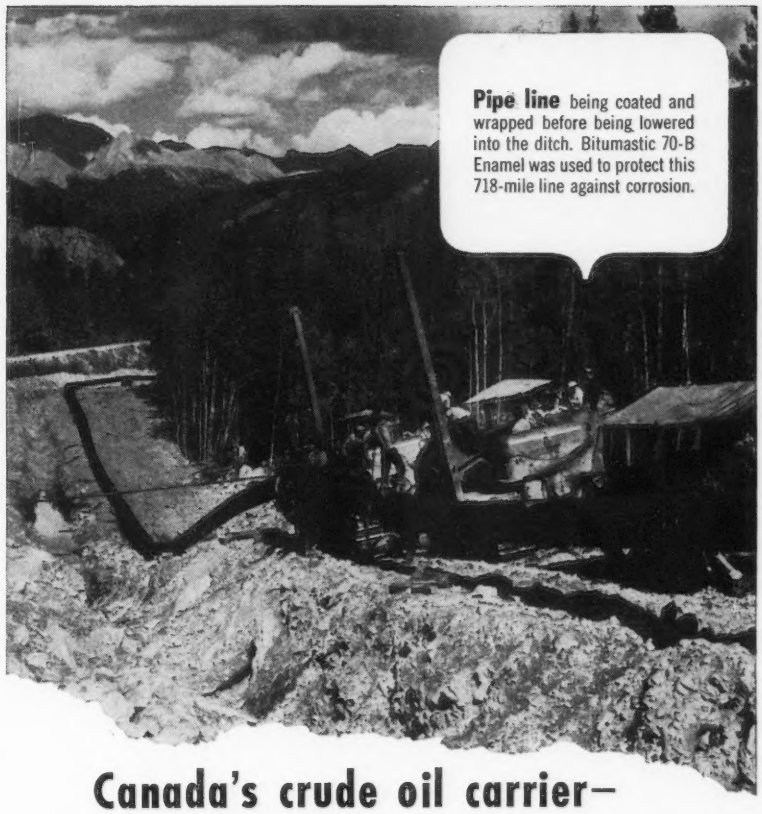
The commission revealed that studies are being made involving separate investigations of each industrial plant and stretch of stream on which it is located. Engineering and economic appraisal for each situation rather than application of broadside prohibitions will provide maximum beneficial use of water resources in the public interest, it stated.

Photoelectric Meter Gauge Ozone Automatically

A photoelectric instrument for automatic, around-the-clock measurement of ozone has been constructed by the Air Pollution Foundation, 704 So. Spring St., Los Angeles 14. Device is of two parts, a projector and receiver. Operation of instrument is based on ozone's ultraviolet light absorbing characteristic, foundation says. Projector sends ultraviolet rays across path of ozone molecules between it and receiver and measures amount of light removed from path, foundation explains. Amount of ozone in air is then calculated mathematically it said.

Data on Airborne Dust

Size Distribution and Concentration of Airborne Dust is title of technical paper by Kenneth T. Whitby, research associate and Axel B. Algren and Richard C. Jordan, professors, University of Minnesota, which is to be presented during the Semi-Annual Meeting of the American Society of Heating and Air-Conditioning Engineers scheduled at the St. Francis Hotel in San Francisco, June 27-29.


Pipe line being coated and wrapped before being lowered into the ditch. Bitumastic 70-B Enamel was used to protect this 718-mile line against corrosion.

Canada's crude oil carrier—

Trans Mountain Oil Pipe Line

—protected by Bitumastic 70-B Enamel

A river of oil now rolls all the way from Edmonton, Alberta, to Vancouver, British Columbia—a distance of 718 miles. Each day, more than 100,000 barrels of crude oil can be pumped through the Trans Mountain Oil Pipe Line that was recently completed.

Building this new 24-inch pipe line wasn't easy. Mountains had to be climbed. Rivers had to be forded—forded, at times, by using sealed sections of pipe as pontoons for temporary bridges. In some mountainous terrain, after using trucks, tractors and winches, pipe had to be carried into position, piece by piece.

A pipe line laid in such rough terrain deserves exceptional protection against corrosion. Recognizing this, Trans Mountain has coated the exterior surfaces of its new line, all 718 miles of it—with Bitumastic® 70-B Enamel. More than 20 years of satisfactory service protecting oil and gas pipe lines prove that Bitumastic 70-B Enamel is an excellent corrosion barrier.

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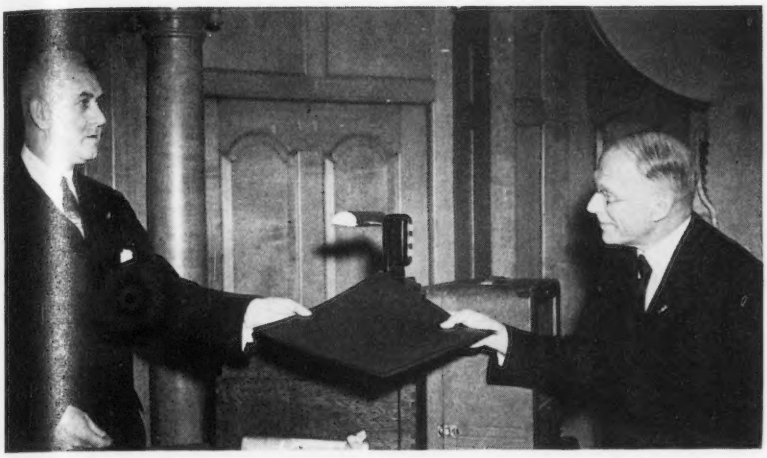
General News



FORMAL PRESENTATION of the NACE 1955 Whitney Award was made by F. L. LaQue, International Nickel Co., Inc., New York (left) to W. H. J. Vernon, consultant, formerly head of the Corrosion Group, Department of Scientific and Industrial Research, Teddington, England in London, March 30. Mr. LaQue, formerly a president of NACE, who is touring Europe, presented the award on behalf of NACE.

Cebelcor Hears LaQue At Brussels April 13

F. L. LaQue, head of the research and development division of the International Nickel Co., Inc., New York City spoke on the subject of corrosion research at Brussels, Belgium on April 13. His address was a feature of the April 13-14 meeting of corrosion workers under auspices of Centre Belge D'Etude de la Corrosion. A discussion in English and French followed Mr. LaQue's address.

Other items on the program included:

Report on the activities of Cebelcor by M. Pourbaix, director; A. M. Abd el Wahed, E. Deltombe, N. deZoubov, J. Laureys and J. van Muylder.

Fundamental Research into the Electrochemical Behavior of Metals: A Compendium of Electrochemical Equivalents, Predicting the Conditions for Corrosion and Non-corrosion of Metals and Alloys, Predicting Electrochemical Reactions at High Temperatures and Pressures, Electrochemical Catalysis of Chemical Reactions.

Cathodic Protection: Conditions of Passivation and Cathodic Protection of Lead and Lead Alloys.

Anodic Reactions.

A discussion was held also concerning the effect of corrosion on the chemical and metallurgical industries, foundries, water gas plants and the petroleum industry.

Fall AIChE Meeting

The fall national meeting of the American Institute of Chemical Engineers will be held September 26-28 at Lake Placid, N.Y.

University of Melbourne Schedules Corrosion Session

A symposium on Corrosion will be held early in December at the University of Melbourne, Victoria, Australia. Arrangements for presentation of about 30 papers by overseas and local authorities are being made under a committee headed by Prof. H. K. Worner.

Topics to be covered include fundamentals, underground and underwater corrosion, corrosion in industry and in power production.

Secretary of the Committee is G. M. Willis, Metallurgy Dept., University of Melbourne, Carlton N. 3, Australia.

MIT Elevated Temperature Program Set July 11-22

Plans for a two-week Special Summer Program on Behavior of Materials at Elevated Temperatures to be given at Massachusetts Institute of Technology July 11-22 have been announced. Nicholas J. Grant, associate professor of metallurgy will direct the program.

Among the topics to be considered are alloy development, important alloy systems and alloy behavior.

Details and application blanks can be obtained from the Summer Session Office, Room 7-103, MIT, Cambridge 39, Mass.

Madrid Chemical Congress

The 28th International Industrial Chemistry Congress will be held October 23-31, 1955 at Madrid. A session on corrosion and materials protection has been scheduled. Papers to be presented are being accepted by the Organizing Committee, Serrano, 150, Madrid.

Electrochemical Society's May Meeting Features Many Corrosion Papers

Following papers were to be presented during the Technical Program of 107th Meeting of The Electrochemical Society scheduled in Cincinnati, May 1-5.

Inorganic and Organic Synthetic Fiber Papers for Reinforced Plastic Laminates by H. F. Arledter, Hurlbut Paper Co., South Lee, Mass.

The Manufacture and Properties of a Novel Reinforced Plastic by J. W. Case, Bureau of Ordnance, Navy Department, Washington, D.C. and J. D. Robinson, Firestone Tire and Rubber Co., Akron.

Epoxy Resin Glass Base Laminates by J. C. Pitzer, Formica Co., Cincinnati.

Stress Corrosion Cracking in Magnesium by D. K. Priest and M. G. Fontana, Ohio State University, Columbus.

Electropolishing from the Viewpoint of Surface Metallurgy by C. L. Faust, Battelle Memorial Institute, Columbus.

Chemical Polishing of Metallographic Specimens by H. W. Schadler and J. E. Burke, Research Lab., General Electric Co., Schenectady.

Concentration, Polarization and Overvoltage by C. V. King, Dept. of Chemistry, New York University, New York City.

Ion Distribution during Electrolysis by H. P. Dengler and H. B. Linford, Dept. of Chemical Engineering, Columbia University, New York City.

Fundamental Thermodynamics and Kinetics of Electrode Processes by Pierre Van Rysselberghe, Dept. of Chemistry, University of Oregon, Eugene.

Some Applications of the Thermodynamics of Irreversible Electrochemical Processes by Pierre Van Rysselberghe.

Elucidation of the True Mechanism of Hydrogen Evolution, I. Quantative New Consecutive Theory on Smooth Platinum Electrode by A. M. Azzam, Chemistry Dept. Faculty of Science, Ein-Shams University, Cairo, Egypt.

Mechanisms of Hydrogen Producing Reactions on Palladium by J. P. Hoare and Sigmund Schuldiner, Naval Research Lab., Washington, D.C.

Hydrogen Overpotential Studies on Aluminum by D. J. Hansen and F. E. W. Wetmore, Electrochemical Lab., University of Toronto.

Hydrogen Overpotential on Silver Single Crystals by H. B. Morley and F. E. W. Wetmore, Electrochemical Lab., University of Toronto.

Dissolution of Metals in Avids, III. Kinetics by A. C. Makrides, Institute for the Study of Metals, University of Chicago.

(Continued on Page 88)

Sulfur Dewpoint Corrosion Continues to Be Important Problem

Sulfur dewpoint corrosion continues as an important problem in steam power stations and some gas-turbine applications, according to paper entitled Sulphur Dewpoint Corrosion In Exhaust Gases by R. L. Coit, Westinghouse Electric Corp., Philadelphia, scheduled for presentation during the American Society of Mechanical Engineers Diamond Jubilee Spring Meeting in Baltimore, April 18-21. Mr. Coit states low-temperature corrosion occurs at any point where exhaust gases contact cool surfaces in gas-turbine field and says dewpoint corrosion is likely to occur in waste-heat recovery devices for gas turbines.

Author reveals flue gases from steam generators or gas turbines usually have calculated water dewpoint of 100 F, with surfaces of various heat-recovery components normally arranged so metal temperatures are above calculated dewpoint to prevent condensation of moisture. In many instances, he says, part of sulfur in fuel leaves combustion zone as sulfur trioxide. Process by which this occurs is not well known but widely held view is that substances such as iron oxide, iron sulfate and vanadium oxide act as catalysts to accelerate conversion, he said. After sulfur has been oxidized to SO_3, a gas-phase reaction occurs at a temperature well above dewpoint and SO_3 combines with water vapor to form sulfuric acid, Mr. Coit points out.

Sulfur Percentage Small

Author explains that percentage of sulfur in fuel is small and proportion oxidized to SO_3 is also small but may be sufficient to increase dewpoint as much as 250 F with dewpoint of exhaust gases as high as 350 F making it economically unfeasible to maintain all metal temperature above dewpoint. Thus condensation of sulfuric acid occurs on cool surfaces and intensive corrosion results, he says.

In his conclusions, Mr. Coit reveals static exposure tests indicated N 155, Type 310 and Type 304 stainless steels were satisfactory for use in sulfuric acid concentrations of less than 0.8 percent but suffered rapid attack when exposed to 50 percent solution of acid with Hastelloy C appearing most resistant of alloys tested.

A phenolic resin to coat acid containers appeared most suitable to protect copper from acid attack but was badly attacked in semi-closed test heat exchanger when one percent sulfur fuel was used, he said. Mr. Coit felt this indicated no suitable coating is presently available to protect heat exchanger surface materials from corrosion when high sulfur fuels are used and stated tests with very low sulfur fuel (0.005 percent S) showed marked reduction in corrosion attack.

Some Alloys Resistant

In series of rotating tests simulating compressor-inlet conditions Type 316 stainless steel, Inconel, Carpenter No. 20 and Discaloy had high corrosion resistance while 12 percent chrome, Corten, Mayari-R, aluminum-bronze and aluminum-nickel showed high rates of corrosion.

In low-temperature, moderate gas-velocity regions as found in precoolers, intercoolers and waste-heat recover units, Type 316 stainless steel and Hastelloy C appeared to have good acid resistance.

Mr. Coit felt that promising scheme for minimizing low-temperature corrosion in semi-closed cycles for gas turbines is direct-contact coolers (spray cooling) to replace surface types of precoolers and intercoolers. He mentioned that study is being made to evaluate possibility of replacing conventionally designed precooler with spray cooler in which gases are cooled by contact cooling with water droplets. He explains condensation of acid would occur on water droplets and acid concentration would be reduced to less corrosive level.

Paper contains descriptions of tests on alloys and coatings.

Copies are available from The American Society of Mechanical Engineers, 29 W. 39th St., New York 18. Per copy 50c (25c to ASME members).

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Unknown Factors in Boiler Water Treatment Reviewed

The multitude of unknown factors involved in the treatment of boiler waters to prevent scale and corrosion are considered by Frank U. Neat, Senior Engineer, Consolidated Gas Electric Light and Power Co., Baltimore in his paper "Is Chemistry in the Power Plant an Exact Science?" The paper was presented at the April 18-21 American Society of Mechanical Engineers meeting in Baltimore.

Mr. Neat recounts his experience with treatment of water for prevention of caustic embrittlement, oxygen scavenging methods, pitting corrosion, ammonia, amine inhibitors, the alkalinity argument and hide-out. The arguments for and against acid cleaning of boilers also are explored.

Electrochemical Society—

(Continued From Page 87)

Anodic Polarization of Titanium in Nonaqueous Base Etching Solutions by Morris Eisenberg and R. E. De La Rue, Stanford Research Institute, Stanford, Cal.

Oxide Film Formation on the Surface of Metals in Aqueous Solutions and the Evaluation of Their Standard Potentials, III. The Lead Electrode by S. E. S. El Wakkad and T. M. Salem, University of Pennsylvania, Philadelphia and Cairo University, Cairo, Egypt.

Anodic Oxidation of Zinc and Zinc-Tin Alloys at Very Low Current Density by S. E. S. El Wakkad, A. M. Shams Eldin and H. Kotb, University of Pennsylvania and Cairo University.

Anodic Oxidation of Metal Ions to Insoluble Higher Oxides with Special Reference to Maganese Dioxide by H. K. Chakrabarti and T. Banerjee, National Metallurgical Lab., Council of Scientific and Industrial Research, Jamshedpur, India.

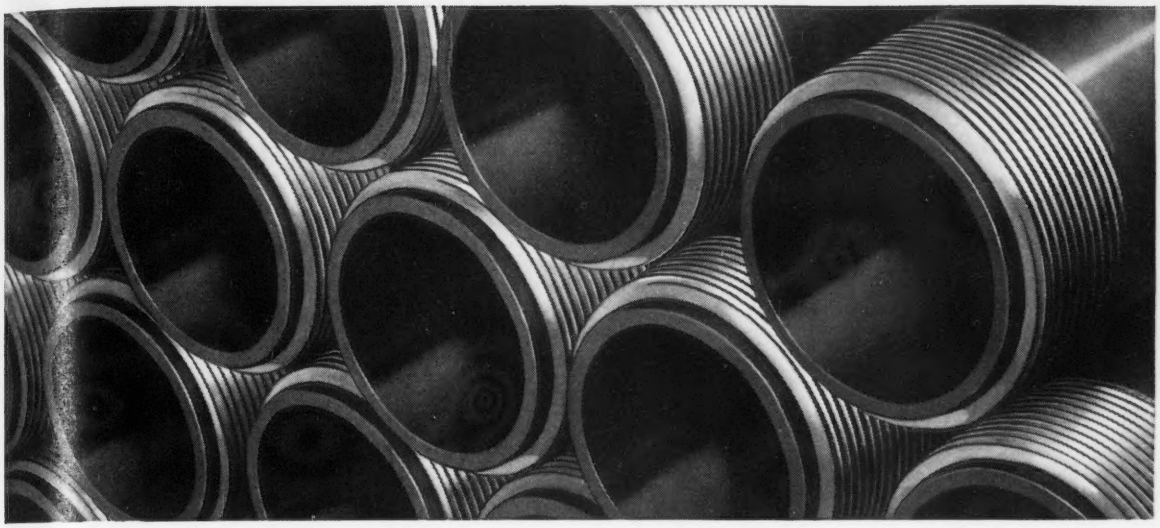
Mathematical Studies of Galvanic Corrosion, II. Coplanar Electrodes with One Electrode Infinitely Large and with Equal Polarization Parameters by J. T. Weber and Marshall Rosenbluth, University of California, Los Alamos Scientific Lab., Los Alamos, N. Mex.

Mathematical Studies of Galvanic Corrosion, III. Semi-Infinite Coplanar Electrodes with Equal Constant Polarization Parameters by J. T. Weber.

Mathematical Studies on Galvanic Corrosion, IV. Influence of Electrolyte Thickness on the Potential and Current Distributions over Coplanar Electrodes Using Polarization Parameters by J. T. Weber and Marshall Rosen- University of California, Los Alamos Scientific Lab., Los Alamos, N. Mex.

Polar Properties of Solvent and the Conductance of Electrolytes at Infinite Dilution by E. S. Amis, Dept. of Chemistry, University of Arkansas, Fayetteville, Ark.

DOW



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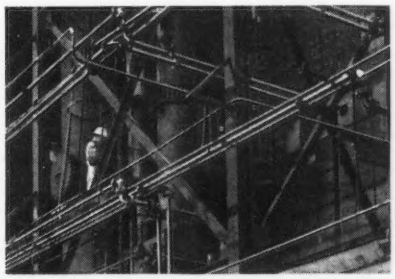
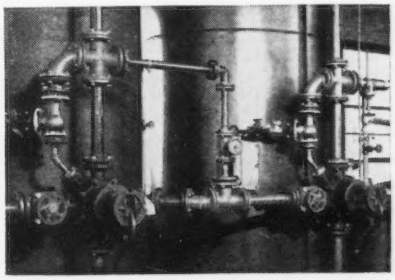


Hydrochloric acid has been conveyed in this installation for well over seven years. Service has been eminently satisfactory.



Saran lined pipe is used here in an automatic water de-ionizer. This installation has also had a long record of uninterrupted service.

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Corrosion Engineer—11 years experience in corrosion mitigation work dealing with transmission and distribution pipe lines, tank bottoms and lead-sheathed cables. Excellent references. CORROSION Box 55-18.

•

NACE Abstract Card Service consists of about 2000 2-row punch cards a year with abstracts of corrosion literature printed on them. They are cross-indexed and punched by topics.

Alkaline Chromate Process Details Given by NBS

A low-voltage alkaline chromate process for depositing protective coatings on magnesium alloys has been investigated by National Bureau of Standards electro-deposition laboratories under sponsorship of the Department of the Army. Coatings produced by method provide protection against salt-spray corrosion equivalent to coatings obtained from other anodizing processes, NBS stated. It revealed process is potentially more economical than other methods because it uses low-voltage power supply and, in addition to water, requires only two constituents, sodium or potassium hydroxide and corresponding chromate.

Process is similar to electroplating except alternating current is used and coating forms on both electrodes, NBS explains. Some material is deposited out of solution onto electrodes in anodizing process but coating is mainly material formed by chemical reaction between metallic electrode and electrolyte components, it said. A current of 80 to 140 amp/ft² is passed through bath for 20 to 40 minutes at 150 to 170 F and coating of 1 to 2 mils thick forms on magnesium alloy electrodes, NBS pointed out. Coating is smooth and gray-green in color but not as uniform in appearance as HAE or acid chromate coatings and gas adsorption measurements (Brunauer-Emmitt-Teller method) reveal coating has smaller effective area than HAE coatings, NBS said. If anodized panels are bent or flexed coatings crack on tension side of bend and chip or shatter on compression side, it stated.

Temperature Range Is Limited

While coating distribution is not as uniform as those produced by processes requiring high voltages such as HAE process, it is more even when suitable racking procedures are used, NBS explained. Complete coverage can then be obtained over limited range of temperatures for given current density; for example, if process is operated at 80 amp/ft² a temperature of 60 C is required to obtain complete coverage of specimen panels, it said. At lower temperatures panels remain bare near edges, at higher current densities minimum temperatures required for complete coverage are higher and indications are that temperatures above 75 C yield coatings having poorer corrosion protection, the bureau revealed.

Work shows coatings produced in alkaline chromate baths are resistant to salt spray corrosion, NBS says. It stated corrosion resistance of coatings from many baths of various compositions including HAE and acid chromate were compared with alkaline chromate bath coatings and latter appeared most resistant when exposed to salt spray in equipment operated according to Federal Specification QQ-M151.

AC Bath Coatings Better

Salt-spray protective value of coating is controlled by current density and bath temperatures and variations in current between 80 and 140 amp/ft² have little effect on corrosion resistance but lower current densities yield coatings of inferior protective value, NBS revealed.

(Continued on Page 92)

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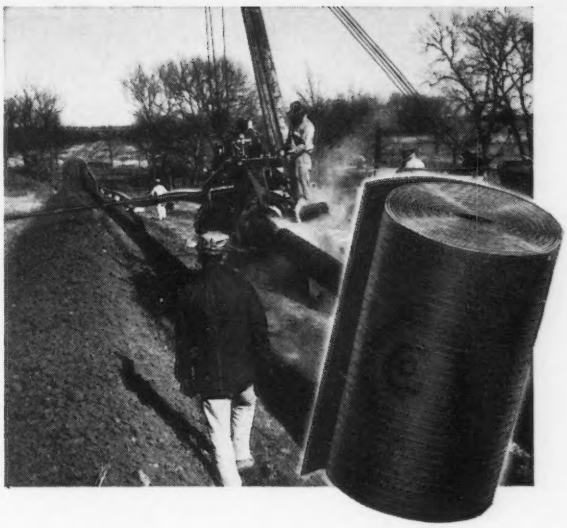

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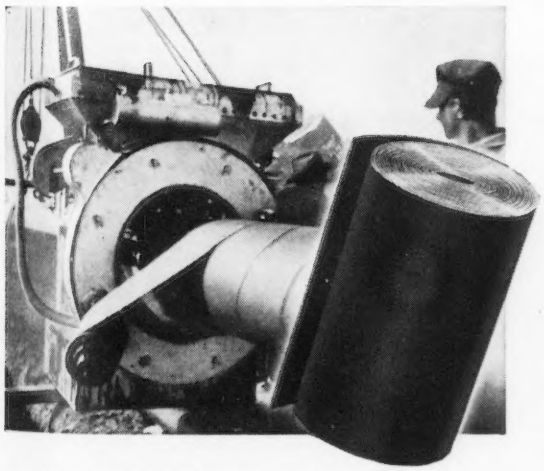
This newly developed low cost pipe line protecting wrapper is designed for average soil conditions. It is reinforced with continuous glass yarns, parallel spaced on ¼" centers to give tear-free application strength. Made of coal-tar saturated asbestos, it acts as a continuous barrier to shield pipe line enamels from earth loads and soil stresses.



15-LB. ASBESTOS Pipe Line Felt—

A heavy-duty material particularly suitable for severe soil conditions or where a heavier material than J-M Transhield is desired. Provides long life, toughness, flexibility, resistance to rot, decay, cracking, and impact. J-M 15-lb. Asbestos Felt now protects more than 100,000 miles of oil and gas pipe lines. Widths 2" to 36". Rolls any length desired.

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For further information about Johns-Manville Products for Pipe Line Protection, write to Johns-Manville, Box 60, New York 16, N. Y.; in Canada, 199 Bay St., Toronto I, Ont.

JOHNS-MANVILLE JM PRODUCTS

Johns-Manville PRODUCTS FOR PIPELINE PROTECTION

Zinc Anodes Perform Satisfactorily in Sea Water Piling Installation

Satisfactory performance of zinc anodes cathodically protecting a piling of a pier in sea water was reported to the American Zinc Institute, Inc. at its April 29 meeting in Chicago. A. W. Peabody, Ebasco Services, Inc., said increased sea water temperature with the return of warmer weather has been accompanied by an increase in output of the anodes, indicating that they have not become passive.

Mr. Peabody also reported eight-foot-long cast zinc anodes for grounding electrical structures may be fabricated by joining shorter anodes, or replaced by link-type anodes. Use of a number of short anodes is suggested as a means of getting better current distribution.

Use of zinc anodes in pairs as a type of electrolytic grounding cell for controlling induced AC potentials on underground coated structures paralleling high voltage transmission lines is increasing, he said. They also are being used for protection of insulating flanges of underground piping subject to damage from high voltage surges initiated by lightning or ground fault conditions on paralleling high voltage electric transmission systems.

Increased use of coatings heavily loaded with powdered zinc also was reported by Mr. Peabody. He said these coatings were used in the expectation they would provide cathodic protection for the covered surfaces in much the same way that galvanizing functions. The use of zinc anodes for cathodic protection of underground gasoline tanks, fuel oil tanks and associated piping in service stations also is arousing interest. Certain precautions in connecting electrically all underground structures involved in such installations were recommended.

Zinc may prove more economical than magnesium for installations where soil resistances on the order of 1500 ohm/cm are encountered, he said.

Cathodic protection of domestic fuel oil tanks also offers a market of considerable magnitude, Mr. Peabody pointed out.

Automotive Engines Cause 45 Percent of Los Angeles Air Contamination Load

In the Los Angeles area 45 percent of the daily emissions of significant pollution into the air are by automotive internal combustion engines, according to Dr. Lauren B. Hitchcock, president of the Air Pollution Foundation. Dr. Hitchcock told a meeting of the American Petroleum Institute April 28 at Los Angeles that the foundation calculates the oil industry currently is emitting 600 tons of pollutants daily, or about 18 percent of the daily 3300-ton total.

Of the remainder 20 percent is from domestic use of natural gas and incinerator burning, 10 percent by miscellaneous industrial, operations and 7 percent by evaporation at service stations and gasoline losses in automobiles.

Dr. Hitchcock said that the oil industry has reduced its emission of pollutants by more than half since first estimates of the pollution problem are made. He said that each factory and each home owner must endeavor to reduce his contribution to pollution if any significant progress is to be made. "It is up to the residents of Los Angeles Basin how long it will take to eliminate smog, he said.

Irradiation Tested As Sewage Sterilizer

Sterilization of sewage by irradiation can be effected without activation or leaving residual radiation in the treated liquids. Waste products from atomic power plants are visualized as one source of required radioactive materials by Harry N. Lowe, Chief of the Corps of Engineers Laboratories' Sanitary Engineering Branch, Ft. Belvoir, Va.

The research and development laboratories have conducted a six-months' inquiry into the possibilities of using gamma radiation to sterilize sewage, drugs and antibiotics, meat and other foodstuffs and decrease the number of bacteria in swimming pools without using chlorine.

Corrosion Interest Papers At AWWA June Meeting

Papers of corrosion interest scheduled to be given during the June 12-17 annual conference of the American Water Works Association are as follows:

Corrosion Problems in Small Heating Boilers by H. F. Hinst.

Design of Cement Lined Steel Pipe by E. S. Cole.

Electrical Inspection of Coatings on Steel Pipe by Mark Davidson.

New Developments in Tests of Coatings and Wrappings by G. E. Burnett and Paul W. Lewis.

Effects of Physical Environment on Water Mains by Clarence F. Decker.

Effect of Water Treatment on Water Mains by A. M. Buswell.

The Solution Effects of Water Upon Cement and Concrete Linings of Water Mains by M. E. Flentje and R. J. Sweitzer.

A 15-Year Exposure Test on Three Types of Distribution Pipe by M. J. Shelton.

New Correspondent

Franz Ritter, Linz, Austria has been named successor to Dr. E. Fitzer as correspondent in Austria for the Inter Society Corrosion Committee. Dr. Ritter reported a Corrosion Association of Austria has been founded and that he attended the May 19 meeting at Frankfur am Main where a European conference on the formation of a federation of European corrosion specialists was discussed.

Mulock Is Elected

F. S. Mulock, president of U.S. Smelting, Refining and Mining Co., Boston has been elected president of the American Zinc Institute. Three vice-presidents also named were C. Merrill Chapin, Jr., St. Joseph Lead Co., New York City; R. G. Kenly, New Jersey Zinc Sales Co., New York City and E. H. Snyder, Combined Metals Reduction Co., Salt Lake City, Utah.

Alkaline Chromate—

(Continued From Page 90)

It pointed out that increasing temperature above complete coverage requirements also tends to reduce protection against salt spray. Direct current has been used in process to produce uniform coatings on panels in solutions of appropriate composition but salt spray tests indicate these panels were somewhat inferior to those coated in preferred a-c bath, NBS said.

Several organic coatings such as lacquers or paints were tested for adhesion to chromate coating as part of the investigation with adhesion being satisfactory if specimens were not subjected to bending or flexing, bureau explained. It revealed that when panels are bent, loss of adhesion occurs on coatings 0.5 mil or more thick because of failure of electrodeposited coating. Adhesion is satisfactory on thinner coatings, it said.

NBS stated protective coatings obtained from its simple alkaline chromate process should lead to wider utilization of magnesium alloys for light-weight equipment and for many aircraft and shipboard components where corrosive atmospheres prevent use of the uncoated metal.

Two Channels Used

Authors stress proper recording of test must indicate magnitude of any indication showing in time interval between end of initial impulse and beginning of end return, and amplitude of end return to make sure testing sensitivity remains constant during each test. Specifications are met by automatic recording unit having two independent channels which are identical but "active" at different times. Channel 1 is on during period between end of initial pulse and start of end return and Channel 2 is on during period in which end return is being received. Two multivibrators for each channel control timing of electronic gates that turn each amplifier on and off at proper moment, authors state.

Authors claim the instrumentation offers further approaches to automation in addition to advantage of printing a permanent test record of each item. They point out that a trigger circuit can be made to operate an audible or visible alarm and set off a spray gun to paint location of defect if indication is present with an amplitude exceeding one produced by standard artificial defect. They also suggest that another alarm can be sounded and equipment brought to stop if loss of coupling causes end return to drop below a minimum value.

Quality Control Device

While discussion of application of ultrasonics to product inspection is stressed, authors believe that greatest usefulness of equipment described will be as quality-control tool at producer's plant tracing defects to manufacturing step at which they occur.

A description of delayed shear-wave search unit, the automatic recording system and test results are included with diagrams.

Paper designated as 55-S-23 is available from ASME, 29 W. 39th St., New York 18. Per copy 50c (25c to ASME members).

Automatic Ultrasonic Testing of Small Diameter Tubing Is Possibility

Progress made in ultrasonic test equipment which appears to make automatic testing of small-diameter tubing a possibility is reported in a paper entitled Testing of Small-Diameter Tubing With Automatic Recording Ultrasonic Equipment, by W. L. Fleichmann and H. A. F. Rocha of the General Electric Co., Schenectady which was scheduled during the American Society of Mechanical Engineers Diamond Jubilee Spring Meeting in Baltimore, April 18-21.

Use of pulsed ultrasonic shear waves is most effective method of testing pipe and tubing for longitudinal defects with pulses being introduced at angle by search unit and traveling around object causing echo whenever they meet a discontinuity, authors reveal. They explain echos are received by search unit and appear as "pips" or "indications" on a cathode-ray tube and in absence of discontinuity pulses travel around object producing a constant pip called "end return."

Importance of Slime In Corrosion of Cooling Towers Is Investigated

Slime attached to surfaces in water cooling towers creates conditions which may favor the propagation of sulfate reducing bacteria and, therefore, increase the corrosion rate of the metal. This postulate was tested in laboratory systems simulating cooling tower conditions by R. S. Wise, National Aluminate Corp., Chicago, using two kinds of inhibitor and two kinds of slime organisms.

Results of the tests indicate increased rates of corrosion may be expected, but no reliable quantitative data could be given because of the difficulty of securing slime attachment to the test coupons. The tests were reported in "Significance of Slime in Causing Corrosion and Mechanism of Corrosion by Slime Growths," presented at the American Society of Mechanical Engineers April 18-21, 1955 meeting in Baltimore.

NACE to Use Associated Technical Service Abstracts

Associated Technical Service Abstracts, published by Associated Technical Services, P. O. Box 271, East Orange, N. J. is the 28th organization to authorize the republication of its abstracts by the National Association of Corrosion Engineers. The firm's name will be added to the list of agencies and abstracts it supplies will include the designation "ATS."

•

Prospective authors of technical papers intended for publication in Corrosion are invited to write for copies of the NACE Guide for Preparation and Presentation of Papers.

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Of the 95 articles published in Corrosion's Technical Section during 1955 all but 7 were original material.

TESTS PROVE NEW EASY-TO-APPLY

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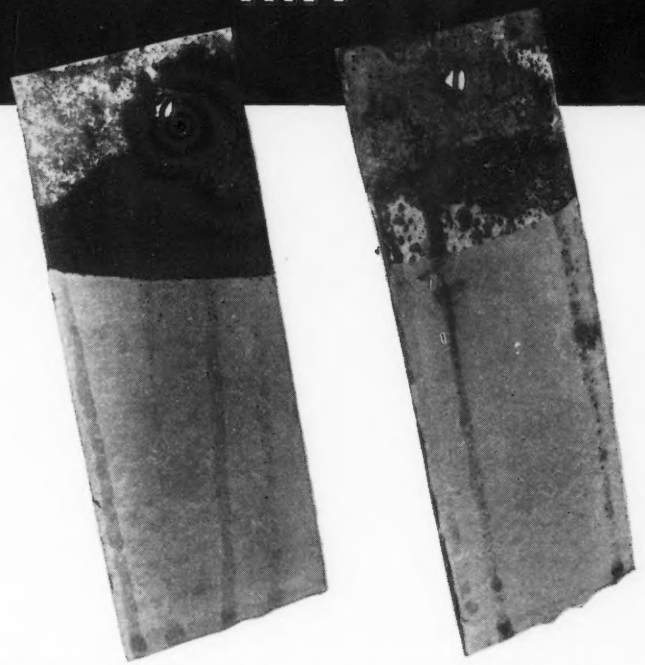

These test panels of rusty steel were coated at the same film thickness and exposed side by side in a highly corrosive atmosphere (35% hydrochloric acid vapors) for the same length of time. Coatings on both panels were identical, with one exception: primer on left panel was new Rustbond #6, that on right was a popular competitive primer. In both cases, the topcoat was the same *well known competitive brand.*

As this unretouched photo shows, the sharp edge protection of the panel at right has completely failed, while the panel primed with Rustbond #6 shows practically no edge failure.

You can get improved performance like this from *any* topcoat—vinyl, phenolic, alkyd—with Rustbond #6 as the primer.

Rustbond #6 offers you these advantages:

- **Dries in only 10 minutes at 85°F., 15 minutes at 70°F., reducing application time and cost.**
- **Can be applied over wirebrushed rusty steel or bright shiny steel.**
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Specialists in Corrosion Resisting Synthetic Materials

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NEW PRODUCTS —Materials—Service—Literature

Wiretex Iconel Conveyor Basket produced by Wiretex Mfg. Co., 40 Mason St., Fairfield, Conn., is said to take three hours to go through complete heat treating, washing and drying cycles when used on automatic jack rabbit salt bath conveyor. No signs of corrosion or warping were evidenced on baskets put into use four months ago on conveyor which operates on 24 hour basis, five days a week, the company says. Basket allows automatic loading and unloading, carries maximum number of parts in minimum space, exposes largest possible surface area of each part to contact with molten salt and quench oil, the company claims.

•

A Flexible Metal hose said to be designed for use in conveying materials having abrasive and corrosive characteristics such as grains, bulk chemicals, ashes and cement is produced by Universal Metal Hose Co., 2137 S. Kedzie Ave., Chicago 23. Hose is available in Type U-100-L standard weight (.015-inch galvanized steel strip) and Type U-120-L heavy-duty (.020-inch galvanized strip), both furnished with .012-inch stainless steel strip liner unless carbon steel liner will satisfy and is specified, the company says.

•

A Pressure-Sensitive tape with Fiberglas backing and inorganic silicone adhesive called Mystik Brand No. 7000-G is produced by Mystik Adhesive Products, 2635 N. Kildare Ave., Chicago 39. Manufacturer claims product combines high tensile and dielectric strengths with excellent bonding ability at temperatures ranging from 100 F below to 550 F above zero and offers high degree of stability in presence of sulfuric, hydrochloric, acetic and nitric acids, lubricating oils and ammonia, chlorine, bromine and iodine. Laboratory tests have failed to disclose corrosive or staining action on wide variety of metals, fabrics, papers and glass, the company says.

•

Aluminum Company of America announces initiation of production at two continuous process aluminum welded tube mills located at its works in Alcoa, Tenn. Mills provide Alcoa with capacity to produce welded aluminum pipe and tubes from ½ to 8 inches in diameter.

•

Self-Contained cartridge roller bearing produced by Rollway Bearing Co., Inc., 541 Seymour St., Syracuse is described in four-page catalog available from the company. Shaft and housing dimensions and bearing radial load ratings at 100 rpm are listed.

•

Pipette Jars made of polyethylene are produced by American Agile Corp., P. O. Box 168, Bedford, Ohio. Manufacturer claims units are chemically resistant to most acids, alkalies and caustic cleaning solutions at temperatures up to 150 F. Important feature is that product's resilence helps prevent breakage of pipettes or pipette tips during soaking or washing operations, the company says.

•

A Truck-Body made of Lamicor, a reinforced fiberglass said to resist most alkali and acid concentrations used in industry, has been constructed for the Carnation Milk Co. of Los Angeles by the Strick Co., Whitaker and Godfrey, Philadelphia 24. Structural framing is molded into outer skin rather than joined to it by riveting or welding, the company says. Use of Lamicor makes truck-body sanitary, easy to clean and corrosion-free. Temperature changes will not harm material and moisture will not cause it to deteriorate or delaminate, the company says.

•

Continuous Rotary vacuum filters with FEinc String Discharge are discussed in the 24-page Bulletin No. 103-B published by Filtration Engineers, Inc., 155 Oraton St., Newark 4. Applications in processing of chemicals, food products, pharmaceuticals, ceramics, starches, industrial wastes and paper and pulp are included with illustrations.

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Improvement of Variable-Area Plexiglas flowmeters by installation of Heli-Coil stainless steel wire thread inserts at inlet and outlet connections is announced by F. W. Dwyer Mfg. Co. of Chicago, producers of the product. Manufacturer recommends meters for use with manometers, in air sampling for smog analysis and industrial hygiene, detection of toxic gases, as replacement for sight-feed bubblers and, as purge meters with other instruments. Standardization of inserts, usually of ⅛-inch pipe thread size, guarantees against thread wear and protects flowmeters against thread-stripping caused by accidental use of too much force in tightening fittings, the company says.

•

A Modified Amine curing agent called Experimental Curing Agent U has been developed by Shell Chemical Corp., 50 W. 50th St., New York. Company says development work has shown agent is particularly useful in epoxy castings, potting and adhesives and laminating applications where room temperature or moderately elevated temperatures of curing are desired. Agent is expected to find widest usage with lower molecular weight resins, particularly Epon 828 and and it can be used with all Epon resins, the company says. In all applications low vapor pressure minimizes odor associated with unmodified polyamines, Shell revealed. A data sheet is available from the company.

•

Pastushin glass-fiber resin tank made of thermosetting polyester-resin reinforced with chopped glass roving is manufactured by Pastushin Aviation Corp., 6901 Melrose Ave., Los Angeles 38. Advantages of tank are corrosion resistance, lower tooling costs, easier storage and field maintenance and use of non-critical material, the company claims. Also, strength is assured by glass contents as high as 60 percent with homogeneous dispersion in resin, the company says.

•

A Norelco X-ray absorption gas analyzer manufactured by Research & Control Instruments Division of North American Phillips Co. Inc., 750 S. Fulton Ave., Mt. Vernon, N. Y. is said to detect elements of high atomic weight in gas mixtures and determine amount present. Analyzer has monocromatic X-ray beam which permits well-defined absorption measurements, is adequately shielded to protect personnel against X-radiation hazards, includes X-ray generator with current stabilizer, Geiger tube, absorption standard, servo motor, gas cell and gas system with pressure regulators and pumps. Installation consists of two units, the analysis assembly and circuit panel. Unit operates from standard 115-volt, 60-cycle, single-phase ac supply circuit, is air-cooled and designed for continuous operation at maximum ratings over ambient temperature range from 60 to 110 F. Also, new applications where X-ray diffraction and spectrographic analysis instruments are helping to solve tough problems are announced by the company. These include such fields as metals (analyses amounts of silicon and aluminum in aircraft alloys), railroads (analyses metals in used crankcase Diesel oil to show unusual wear of engine parts), and oil industry (analyses trace amounts of vanadium and other contaminants in crude and refined oils and analyses trace amounts of sulfur in gasoline, naphtha and other fuels).

•

Babcock & Wilcox Co., 161 E. 42nd St., New York City has announced plans to construct a major plant for manufacture of fuel elements and other reactor core components for nuclear power industry. Kaowool, a pure white homogeneous refractory fiber made by melting and blowing kaolin clay, is manufactured by B&W which it says has insulating value comparing favorably with materials made of fine glass fibers but has additional advantage of withstanding temperatures up to 2000 F without change or loss of resiliency. Fibers of unusual length, up to eight inches and longer can be produced, the company claims. Flightex Fabrics, Inc. has been granted exclusive right to distribute the product to the aircraft industry, the company announced.

•

Magnistors, with three basic circuit elements are produced by Potter Instruments Co., 115 Cutter Mill Rd., Great Neck, L. I., N. Y. Manufacturer claims units can be used in many places where electronic tubes are used with increase in dependability characteristic of magnetic circuits. Principal applications will be in high speed computers, business data handling systems, automation control systems, high speed counters and magnetic tape systems, the company says. R. L. Snyder made the basic invention.

•

Fiberglas Industrial Building Insulation said to provide thermal and acoustical insulation for roofs and walls as well as attractive interior finish is produced by Owens-Corning Fiberglas Corp., Toledo 1. Product is designed for use with protected steel, cement asbestos board, aluminum or painted galvanized sheets for

(Continued on Page 96)

Safeguards Gulf Interstate

Gas Company "PIPELINE ALLEY" System

Typical Rectifier Installation for Corrosion Protection.

CATHODIC PROTECTION EQUIPMENT provided on GULF INTERSTATE GAS COMPANY System from the Gulf Coast to Eastern Markets

Good-All Rectifiers — Rome Direct-Burial Cable — C P S Graphite Anodes, Backfill and Splicing Materials were delivered on schedule as packaged units for installation at 22 points along the 1,150 mile Gulf Interstate Gas Company System, facilitating the speedy installation of the cathodic protection system of this important new pipeline

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NEW PRODUCTS

(Continued From Page 94)

construction of such permanent buildings as warehouses, foundries, low-cost gymnasiums, assembly and manufacturing plants and airplane hangers, the company says. It is rated non-combustible when tested in accordance with Federal Specifications SS-A-118a, the company claims.

•

Dispersion Coatings that include Teflon, a polytetrafluoro-ethylene resin finish, are produced by Electro Chemical Engineering and Mfg. Co., 750 Broad St., Emmaus, Pa. Manufacturer says coatings may be bonded to metals having melting point over 750 F, except copper, by means of special primers and process developed by E. I. du Pont de Nemours & Co., Inc. Primer and finish coats are fused at temperature of approximately 700 F after being spray applied, company says. Coatings are not recommended for protecting metals against attack of severely corrosive chemicals because of certain inherent film porosity which cannot be overcome by multiple coats, the company advises.

•

Four-Page Bulletin 155 on Teflon applications by Sparta Manufacturing Co. P. O. Box 66, Dover, Ohio has been published by the company. It includes latest Properties Table of Teflon.

•

Phenoline 300 series coatings made of modified phenolics are described in four-page Bulletin No. 600 available from Carboline Co., 331 Thornton Ave., St. Louis 19. Bulletin explains company's testing programs, areas where coatings are recommended, classes of industries and applications where Phenoline systems are used and includes corrosion charts.

•

Darsol solvents 650, 600 and 350 designed as replacements for carbon tetrachloride and other toxic solvents are manufactured by Dacar Chemical Products Co., Dacar Chemical Bldg., McCartney at Wabash St., West End, Pittsburgh 20. Products are unusually low in toxicity compared to carbon tetrachloride and are adaptable for metal cleaning where rapid drying and absence of film is required, the company says. Darsol solvents 74-C, 45-A and 62-B produced by the company are said to be general cleaners of the emulsifying type and can be diluted with kerosene or water.

•

Duraface Foamglas, a cellular glass insulating material produced by Pittsburgh Corning Corp., is said to provide durable, impact-resisting surface along with high insulating and moisture-proof qualities. Manufacturer claims a wall completely insulated and surface-finished can be erected in one operation with no protective finish coating required and unsupported walls can be built of the blocks because of rigidity and high compressive strength. Having three-quarter inch thick hard white crust on surface, material is completely inorganic, will not rot or deteriorate, is not affected by fungus and walls are easily washed down, the company says. Because it is made of pure glass, product is resistant to nearly all chemicals, the company stated.

•

Electro-Zinc plated sheet metal flexible ball joints are produced by Spincraft Inc., 4132 W. State St., Milwaukee. Of three piece construction pre-assembled, units are easily positioned, require no heavy supports, are corrosion-resistant and weigh 75 percent less than conventional cast-iron ball joints, company claims. Manufacturer points out that 7-inch and 9-inch sizes provide total arc of 45 degrees and all other sizes permit 55 degrees total deflection.

•

The DeVilbiss Co., 300 Phillips Ave., Toledo 1, manufactures a catalyst gun which it says is engineered to provide thorough intermixing of catalyst and resin to eliminate problem of "pot life" which limits use of catalyst materials in production operations. Gun has one head and two elements are mixed outside air cap, company claims. New materials to withstand corrosion or destruction from catalyst or resin are used in production of pressure tanks, guns and hoses for application work.

•

P&H Stainless Steel Equipment is described in a 16-page catalog, SE55, available from P&H Sales Corp., 5650 N. Western Ave., Chicago 45. Booklet covers such items as stainless steel thermostatic water mixer, hospital and chemical lab sinks, cut film tanks and deep roll processing equipment.

•

Amercoat No. 87 Vinyl Mastic protective coating said to have double the solids content of standard vinyl resin paints is produced by Amercoat Corp., 4809 Firestone Blvd., South Gate, Cal. Manufacturer claims coating can be applied at thickness of 10 mils in single double-pass spray coat and does not flow away from edges and sharp corners, thus providing extra protection for areas normally more vulnerable to corrosive attack. Product provides film thickness without sacrificing chemical and moisture resistance, company says.

•

Lagz, a protective coating for thermal insulation compounded from Neoprene, silicone rubbers and other resins is manufactured by West Chester Chemical Co., P. O. Box 39, West Chester, Pa. Product is produced in two Grades. Lagz No. 1, said to be a medium viscosity material for use with 85 percent magnesia, calcium silicate, felt, rock wool or asbestos and applied by spraying, brushing or sponge. Lagz No. 2, which company says is high viscosity material designed for use with low temperature insulation such as cork, foamed plastics, glass fiber or cellular glass and applied by brush or trowel. Both coatings are non-flammable and non-toxic and can be used to fasten insulation to surfaces and cement edges of formed insulation together without use of wire ties or bands, company claims.

•

Apco, a neoprene protective paint produced by Adhesive Products Corp., 1660 Boone Ave., New York 60, is said to have excellent adhesion to metal, wood and ceramic surfaces. Manufacturer claims paint is flexible, will resist shock and dries within 30 minutes.

•

A 12-Page Booklet entitled "Atomic Tools" published by Isotope Products Ltd., Oakville, Ontario, is available from the company for industries desiring copies for plant workers. Booklet provides brief information on such subjects as radioactivity, betameters, gammagages and gamma cameras as well as special advantages of atomic tools. Company reports in Vol. 4, No. 2 of Canadian Isotope Newsletter dated February 1955, that it has used cobalt 60 radiation to take radiography pictures through foot-thick concrete wall.

•

A High Pressure Hydraulic hose designed to operate at 3000 psi is produced by Resistoflex Corp., Belleville, N. J. Designated Fluoroflex-T YR700, hose will withstand all presently known synthetic or petroleum-based hydraulic fluids, the company claims.

•

Standard Philadelphia Pumps equipped with solenoid or air-cylinder operated single-revolution clutch which in normal position is disengaged and motor and gear reducer are always running is produced by Philadelphia Pump and Machinery Co., a subsidiary of American Meter Co., 1513 Race St., Philadelphia. Called Uni-Feeder, pump offers broad field of application, company claims. When solenoid or air-cylinder is energized, clutch becomes disengaged allowing pump to go through one complete cycle for which its capacity has been previously adjusted to provide exact slug of fluid desired, company reveals. Energizing is by electrical contacts or air-sending devices in bulk line and may be controlled according to time cycle, flow, pH color, concentration or any other meterable factor, company explains. Pumps are available with .000093 gallons minimum to 27 gallons maximum per minute capacities. Catalog S-1254 describing product is available from company. Bulletin LP-1254, on Packaged Chemical Feed Systems for

(Continued on Page 98)

Lapel Pins

Approx. Size

Approximately 7/16 inches high, gold, inlaid with bright red enamel background to "NACE" and deep blue enamel background to words "CORROSION CONTROL." Ruby center.

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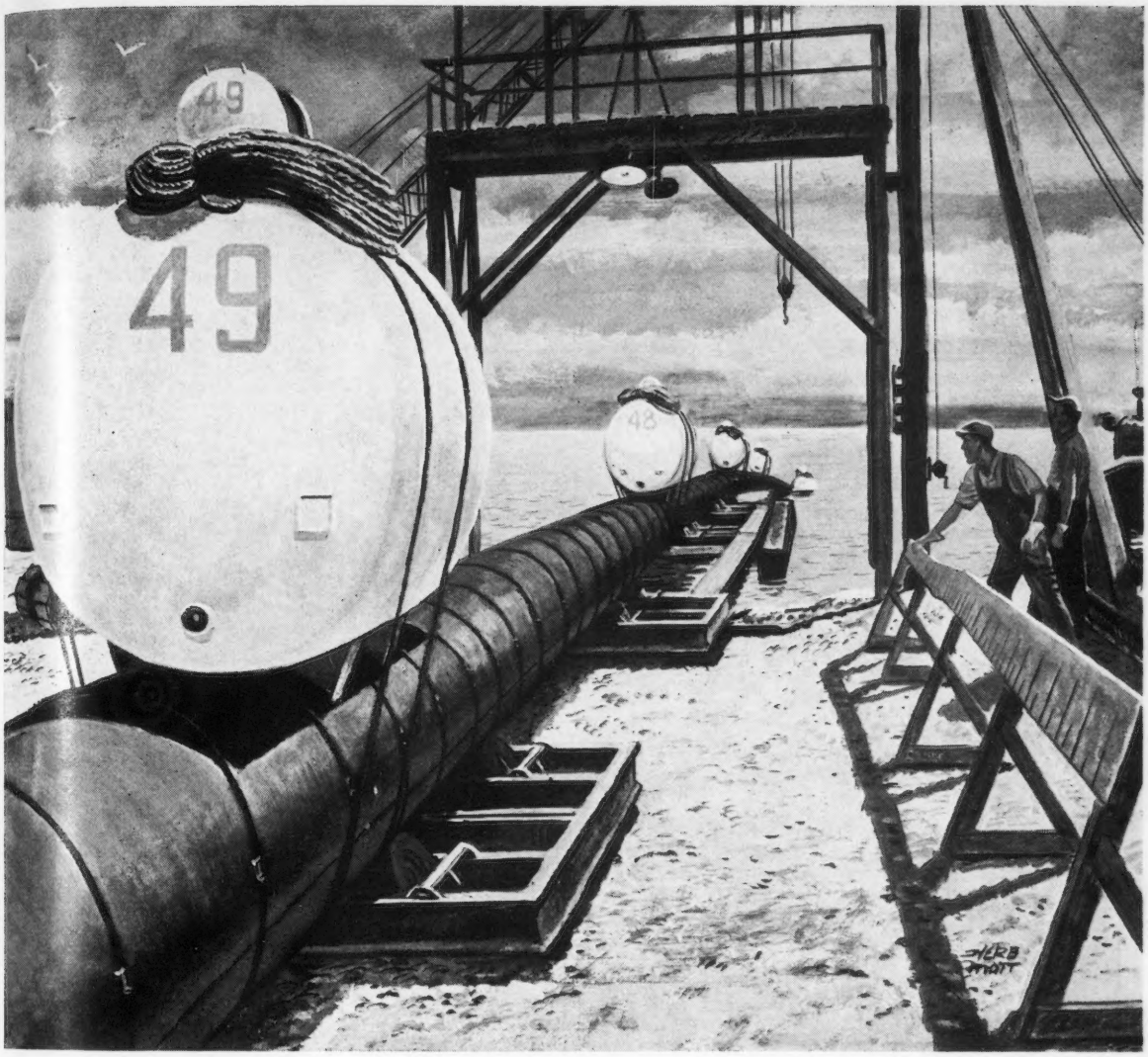

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BARRETT PROTECTIVE COATINGS

100 YEARS OF EXPERIENCE

NEW PRODUCTS

(Continued From Page 96)

general water treating requirements and individual chemical processing needs is available from the company. Philatrol, a patented mechanical link between a proportioning pump and control motivating equipment (manual, hydraulic, pneumatic or electric) for adjustment of piston stroke length and pump capacity while running is manufactured by the company and is described in Bulletin S-1254 available from the company.

•

A Mylar Pressure-Sensitive film tape using inorganic silicone adhesive and said to have dielectric strength of 9000 volts is manufactured by Mystik Adhesive products, 2635 N. Kildare Ave., Chicago 39. Known as Mystik Brand No. PD 300, tape has no corrosion effect on copper and has electrolytic corrosion factor of less than 1.0, the company says. It claims product has been bonded within range from minus 80 to plus 300 F in temperature performance tests and provides resistance to solvents, oil and water immersion, staining and abrasion. Mystik Brand No. 7001, also produced by the company is said to utilize a glass fabric backing and inorganic, semi-cured silastic compound and qualified fully as Class H insulation. Product offers minimum dielectric strength of 1200 v/m and has excellent stability in presence of lubricating oils, sulfuric, hydrochloric, acetic and nitric acids and ammonia, chlorine, bromine and iodine, the company says.

OIL WELL CASING PROTECTED FROM EXTERNAL CORROSION

Magnesium anodes are now being used effectively to stop external corrosion on oil and gas well casing. Here's how one major oil company used this low-cost method on 130 wells, 5000 feet deep:

CSI engineers, who helped develop the method, provided a complete turn-key job. They first surveyed the wells, using special surface instruments,* to determine the current density required for cathodic protection. Then they installed DOW magnesium anodes using CSI equipment and trained personnel. The installation was designed for a 10 year life.

CSI offers expert consultation and installation services, as well as a complete line of brand-name cathodic protection materials—for both anode and rectifier jobs.

Call or write for competitive cost estimates or quotations. Ask about the new Dow "Galvomag" which gives 20 to 35 per cent more current output than other anodes of similar size.

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A New Development in the Production of Metals is title of eight-page bulletin available from the H. M. Harper Co., Morton Grove, Illinois. Booklet explains operation of company's Metals Division and process used in production of corrosion-resistant metals.

•

Peelable Plastic Packaging which includes cellulose acetate butyrate and dioctyl phthalate produced by Eastman Chemical Products, Inc. a subsidiary of Eastman Kodak Co., 260 Madison Ave., New York 16 is said to provide skin-tight overcoat for tools and equipment that protects against tampering and possible corrosion and contamination. Eastman's plastics are combined with certain resins and a rust inhibiting oil into plastic blocks by compounders across the country. When these blocks are placed in specially designed tanks and heated to about 350 F plastic becomes thick, syrupy liquid. Product to be packaged is immersed in molten plastic and withdrawn leaving tough film of plastic 0.05 to 0.1 inch thick over entire surface of product. By slitting plastic with sharp stick in such manner that finished surfaces are not damaged, film can be peeled off like banana skin, the company states. Eastman claims packaging has high flash point, transparency, positive fusion, plasticity, high melting point and resists humidity. Plastic overcoat can be remelted and reused indefinitely, the company says. A 15-minute 16 mm sound movie describing packaging material is available from the company to technical groups, societies and members of industry concerned with protection of unit parts and assemblies in storage or during shipment.

•

Corrosion Control of Electric Light and Power Structures and Equipment is title of 20-page booklet published by Subox Inc., Fairmount Plant, Hackensack, N. J. Booklet includes cathodic protection and paint, painting transformers and substation gear, salvage department painting, fence painting, painting and repainting over galvanizing and general painting hints. A six-page pamphlet entitled Paint Galvanized Transmission Towers for Long Life which presents study of problems involved in painting galvanized transmission towers and other galvanized structures is available from company on request. A four-page pamphlet on anti-corrosive paints provides information on technical properties of company's paints and explains rust-inhibitive properties and durability of special pigment of lead suboxide made by electro-chemical process.

•

A tube, cold drawn from two-inch diameter seamless nickel tubing and measuring 14/10,000-inch in outer diameter has been produced by Superior Tube Co. Norristown, Pa. Inner diameter is about one-third size of human hair and 25 of the tubes equal diameter of 36-gage wire, company claims. Forty-three separate drawing operations with as many intermediate controlled atmosphere annealing operations and use of precision diamond dies to draw sizes from .115 inch down were required to produce tubing, company says.

•

Electronic Parts of intricate shapes and close tolerance produced by U. S. Gasket Co., Camden, N. J. are said to be accurately molded of Bakelite Fluor-

(Continued on Page 99)

NEW PRODUCTS

(Continued From Page 98)

thene and benefit from its strength and dielectric properties over temperature range of 710 F. Bakelite Co., a Division of Union Carbide and Carbon Corp., 260 Madison Ave., New York 16, makers of the fluorthene, claim temperatures of minus 320 to plus 390 F have little effect on product and its low dielectric constant and high dielectric strength make fine insulators and other parts for high frequency radio circuits. Fluorthene can be extruded, coated or case into finished products by conventional processes with only slight adjustments to standard machinery, the company says.

•

Unknown industrial possibilities for two glass reinforced polyethylene tapes are being sought by Minnesota Mining and Mfg. Co., Dept. P-536, St. Paul. Pressure-sensitive No. 875 tape with filaments sandwiched between polyethylene backing and adhesive is said to have tensile strength of 150 psi of tape width and features 9-mils thickness with adhesive gripping on contact. Non-pressure-sensitive No. 877 tape with filaments sandwiched between two layers of polyethylene is said to have tensile strength of 100 pounds psi of tape width and 11½-mils thickness, is activated by temperatures from 275 to 600 F and adheres within 10 to 30 seconds under normal hand pressure. Manufacturer claims backings of both tapes are resistant to most chemicals with exception of hot xylene and low temperature characteristic permits flexibility at —60 F readings. Only known applications are in woven wire and silk screen industry as edge reinforcement and construction industry as reinforcement for lightweight plastic tarpaulins, company says.

•

Model 388 Temperature Indicator —50 to plus 1000 F, said to measure temperature of gases, solutions or solid objects from a distance is manufactured by Simpson Electric Co., 5200 W. Kinzie St., Chicago 44. Meter measures temperature at end of 7½-foot thermocouple lead and size is $7\frac{15}{16}$ x 6 x $2\frac{15}{16}$-inch. It is complete with internal battery and operating instructions and Adjust-A-Vision handle supports instrument at convenient viewing angles, company says.

•

A Polyelectric Chemical flocculant said to remove suspended solids from foundry wash is produced by Monsanto Chemical Co., Springfield 2, Mass. Called Lytron 886, material is partial calcium salt of a carboxyl-containing copolymer of high molecular weight, company says. Sand reclamation systems, dust collectors and normal plant run-offs are three sources of contaminated foundry wash waters company claims. To flocculate resultant mixture, lime is added to produce initial state of incipient flocculation which is completed by addition of Lytron 886 in aqueous solutions, company reveals. Based on solids content of suspension company claims about 0.05 percent Lytron is needed for optimum flocculation and this generally amounts to between two and eight parts per million in settling unit. A 16-page booklet describing material and techniques recommended for use as well as flow diagrams to indicate sequence of unit operations and equipment requirements is available from the company.

Precision Chemical Pump Corp., formerly Precision Machine Co. of Somerville, Mass., has announced relocation of offices and plant at 1396 Main St., Waltham, Mass. Bulletin No. PM 20 published by the corporation describes its Model S heavy-duty, positive displacement, diaphragm type pump for accurately feeding chemical solutions used in water works and industry.

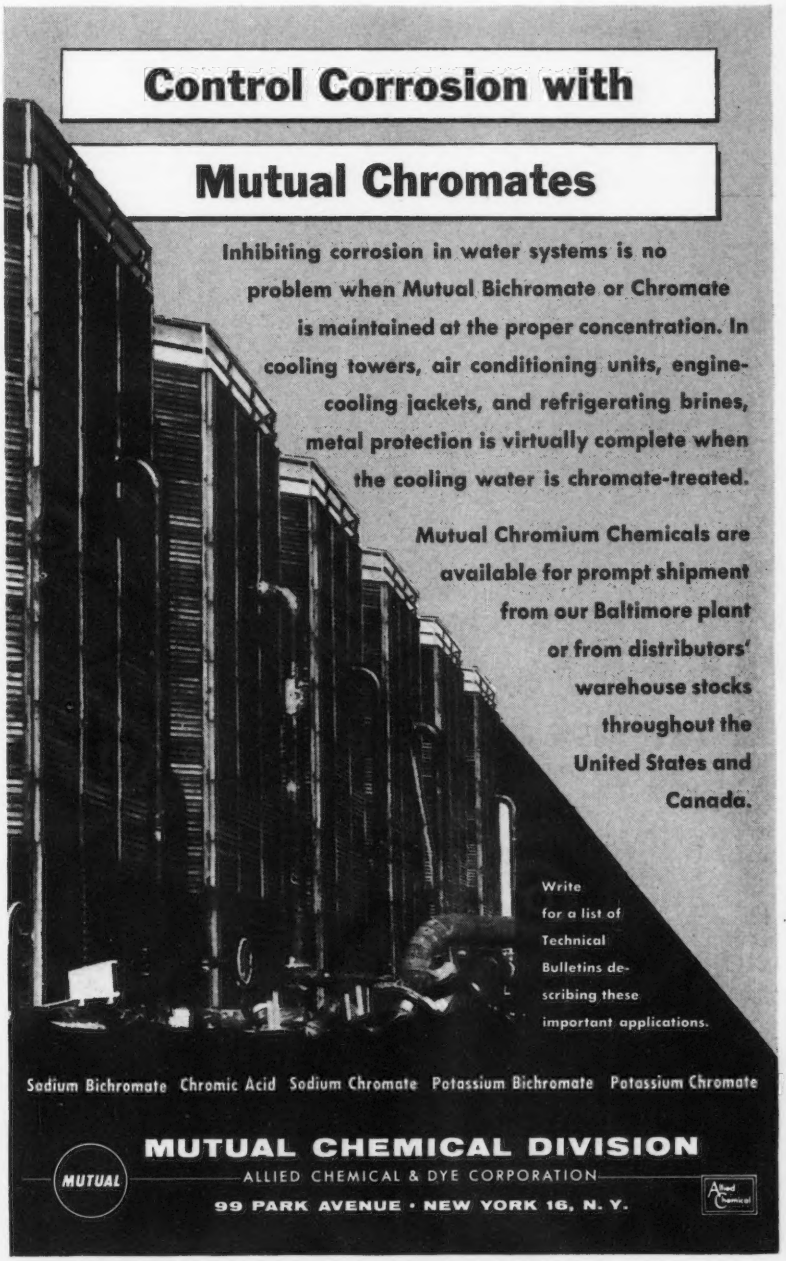
•

Porous Aluminum and aluminum alloys with controlled pore size are manufactured by Micro Metallic Corp. of Glen Cove, N.Y., a member of The Pall Filtration Companies. The powder metallurgy process also is used to make porous stainless steels, Monel, Stellites, nickel and gold, corporation claims. Material can be made in range of thicknesses in excess of 1/32-inch and porous sheet aluminum reveals porous openings of 5 to 150 microns, corporation says. It claims wide range of flow capacities for liquids and gases is possible.

•

Brinalloy, an alloy of nickel, chromium and silicon is recommended as seating and disc material for bronze valves by The Lunkenheimer Company of Cincinnati producers of the product. Company says that during three-year testing program product far outlasted service life of any bronze valve in which it was used eliminating need for renewing, regrinding or replacing seats and discs during entire life of valve. Product is highly resistant to many corrosive chemicals and has tensile strength exceeding 150,000 psi, company claims. Lunkenheimer also manufactures LQ600, a bronze

(Continued on Page 100)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NEW PRODUCTS

(Continued From Page 99)

globe valve with flat seat design and using Brinalloy seats and discs which it claims has not failed or leaked during a four-year testing program even in installations where other valves were replaced regularly from month to month.

•

Low-Hydrogen chrome-moly electrodes, said to be designed for welding of chromium-molybdenum alloy steels in fabrication of high pressure, high temperature piping, boilers and petroleum refining and chemical processing equipment are produced by Metal & Thermit Corp., New York City. Manufacturer claims material designated Murex Croloy has advantages of avoiding high preheat temperatures normally required when welding chromium-molybdenum alloy steels, reduce need for maintaining preheat after welding and prior to stress relieving and in many welds obviate need for stress relieving providing applicable codes permit placing such welds in service without post heat treatment. Lime slag and low moisture content of electrode keep spatter losses at low level and stable arc action assures weld bead with fine ripples and pleasing appearance, company says.

•

The March Corp., 18101 Jas. Couzens Hwy., Detroit 35 has been formed. Company is to engage in applied technical sales of specialized products and services in the high temperature, corrosion resisting and metallurgical fields.

•

Revere Glaswitch, a magnetically operated, sensitive control element for general industrial applications is described in the 20-page Engineering Bulletin 1057 available from Revere Corporation of America, Wallingford, Conn. Booklet covers operation, performance and characteristics of the 2½-inch long, hermetically sealed switch. Methods are illustrated for effecting closure of rhodium plated switch contacts rated at 0.5 amperes resistive or inductive at 28 volts DC or 10 watt lamp load at 115 volts AC. Calibration data, temperature, life and vibration characteristics and installation information are included.

•

"Swish" Aerosol Motor Cleaner and Degreaser, a product of Montgomery Chemical Co., Jenkintown, Pa., is said to soften and loosen grease and oil deposits on automobile engines, marine equipment and other machinery. As grease remover on engines and metal parts product is sprayed over dirty surfaces and allowed to soak in for 15 to 20 minutes before parts are hose rinsed, company says. Manufacturer claims cleaner can remove oily and water-soluble soil from painted surfaces before refinishing and will help remove wet paint stains, oil and grease spots from clothing and upholstery. Du Pont "Freon" fluorinated hydrocarbon propellant is used to provide dispensing pressure in aerosol product.

•

The Electron Microscope is title of a 20-page brochure (Form 3R2546) published by the Radio Corporation of America, Camden 2, N.J. Booklet contains information on capabilities of electron microscopes and describes EMU-1 and EMU-3 units manufactured by the corporation. Copies of brochure are available from Scientific Instruments, Bldg. 15-1, Engineering Division of the Corporation.

•

Nukem Multibond, a polyester resin base cement, said to be made specifically for use as jointing compound for acid brick in corrosion proof installations is manufactured by Nukem Products Corp., 111 Colgate Ave., Buffalo 20. Product is described in four-page pamphlet. Corrosion proof acid brick floors produced by the company are described in a four-page pamphlet. A 22-page Corrosion Engineers Manual contains information on mortar and hot pour type corrosion-proof cements, impervious membranes for steel shell and concrete base equipment and acid/alkali-proof coatings as well as a property chart, estimating chart and resistivity chart. Literature is available from the company on request.

•

Union Carbide and Carbon Corp. announces construction of research laboratories at Parma, Ohio, a southwesterly suburb of Cleveland. To be managed by National Carbon Co., a division of Union Carbide, laboratories' major work is to be on solid state physics research in broad abstract sense as well as practical investigation and design of materials to meet future requirements of industry. Work will also be conducted on metallic and non-metallic compounds of carbon and analagous compounds such as inter-metallics and semi-conductors. Dr. Robert G. Breckenridge has been named to head the research plant.

•

Midwest Research Institute, Kansas City, Mo., announces development of a code library which it says will enhance speed and economy with which engineering computations can be completed in its computing laboratory. Library includes electronic high-speed digital computer to handle variety of technical and scientific calculations and McIlroy Pipeline Network Analyzer (an analog computer) used to obtain immediate displays of flow conditions in complex pipe networks carrying water, gas, oil and other fluids, institute says.

•

Sel-Rex "Little Giant," an 800 gph capacity portable filter said to require only 50 inches of head room and measuring 32 inches in diameter at base is manufactured by Bart-Messing Corp., 229 Main St., Belleville 9, N.J. Unit is constructed of low carbon stainless steel with working parts suspended underneath tank as protection from dirt and drippings, company says. Furnished complete with operating valves, motor and pump, unit is also available with all iron parts for use with alkaline solutions, company states.

•

Facts about Sherarduct, is title of booklet available from National Electric Products Corp., Gateway Ctr., Pittsburgh. Booklet utilizes schematic drawings to show controlled steps in Sherarduct manufacturing process and includes dimensions and weights for conduit, couplings and elbows.

•

Purchase of Assets of the Zapon Industrial Finishes Division of Atlas Powder Co., Wilmington is announced by The Glidden Co., Cleveland. Acquisition includes notes and accounts receivable, patents, formulas, trademarks, certain specialized equipment and sales and technical staffs of the Division. New unit will operate as the Zapon Industrial Coatings Division of The Glidden Co.

•

Colloidal Graphite for Surface Coatings and Impregnation, a revised six page illustrated Bulletin No. 435, is available from Acheson Colloids Co., a Division of Acheson Industries, Inc., Port Huron, Mich. Bulletin describes how electric-furnace graphite of high purity processed to colloidal size and dispersed in suitable carrier is used effectively as surface coating for such devices as high-intensity search lights. Use of colloidal graphite as impregnating medium for

(Continued on Page 101)

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STOCKING AGENTS EVERYWHERE

NEW PRODUCTS

(Continued From Page 100)

such materials as cloth, felt, leather, asbestos and paper are listed also.

•

An Air Operated siphon paint spray gun designated Model P-300 is produced by John B. Moore Corp., P. O. Box 3, Nutley 10, N.J. Manufacturer claims gun is designed to operate on air pressure as low as 5 lb. psi and recommends its use for such jobs as stripe painting, applying silicone mold release oils and application of metal surface corrosion inhibitors.

•

Steel Pipe In New York City's Water Distribution System is title of article by Edward J. Clark, chief engineer, Bureau of Water Supply, Department of Water Supply, Gas and Electricity, New York City which appears in the Spring 1955 issue of Alco Products Review published by American Locomotive Co., Schenectady 5. Mr. Clark explains reasons for installation of more than four miles of 72-inch steel water main in Borough of Queens as link in city's trunk-main expansion program.

•

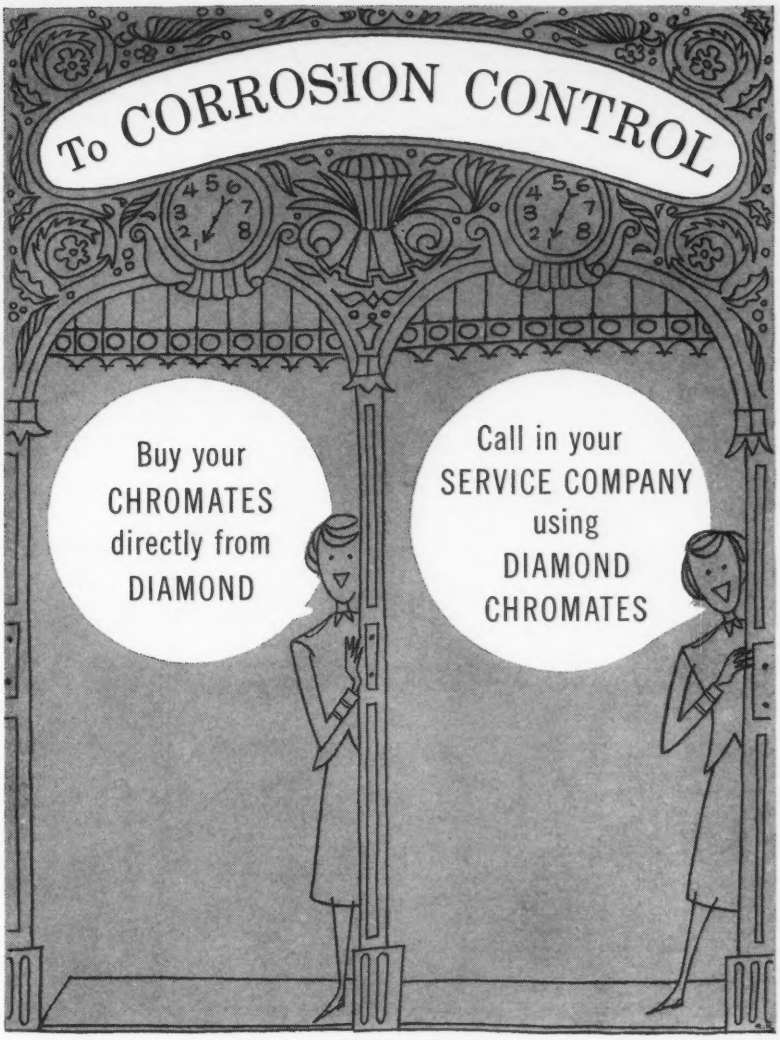
Corrosion Resistance of Cupro-Nickel Alloys Containing 10 to 30 Percent Nickel, a 12-page article by Frank L. LaQue, The International Nickel Co., reprinted from Corrosion, Vol. 10 (1954) November is available from The International Nickel Co., 67 Wall St., New York 5. Also available is a reprint from Corrosion, Vol. 9, No. 8 (1953) August issue entitled Corrosion Resistance of High-Strength Low-Alloy Steels as Influenced by Composition and Environment by C. P. Larrabee, U. S. Steel Corp.

•

Aluminum Alloy 5083, said to be designed for welded structures requiring maximum joint strength and efficiency plus light weight and corrosion resistance is manufactured by Kaiser Aluminum and Chemical Corp., Kaiser Bldg., 1924 Broadway, Oakland 12. Manufacturer claims non-heat-treatable alloy can be welded at high speeds with inert-gas arc welds and has ultimate tensile strength of 52,500 psi with joint efficiencies varying from 75 to 100 percent depending on temper of parent metal. Superior quality welds were obtained at high speeds in all positions of welding during tests, no pre-heating was necessary, distortion presented no problem and less skill was required by welder than on other aluminum alloys, company said. Product has higher strength but slightly lower formability than aluminum-magnesium Alloy 5086, company says. Tensile strength in annealed condition is appreciably higher than Alloy 5052 and more than double 6061 with accelerated and field tests over period of several years in extremely severe environments showing general corrosion resistance to be comparable to 3003 and 6061. Suggested applications include marine uses such as decks, hatch covers, masts and bulkheads. Other applications include flash welded rings, sub-station structures, oil field fabricated parts, chemical storage tanks and pipe lines, company claims.

•

More than 1700 abstracts of technical material published in the world's technical periodicals or books were printed in 1954 Corrosion Abstract Section.



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PERSONALS

Thomas S. Bacon has been named director of the newly created research and development department of Lone Star Gas Company.

•

Robert Jensen has been named Baltimore, Maryland branch manager for Kaiser Aluminum & Chemical Sales, Inc., Kaiser Bldg., 1924 Broadway, Oakland 12. He replaces **Donald C. Heyel** who has been appointed manager of the company's St. Louis sales district.

•

Hugh Wilbanks has been named head of the Corpus Christi office and **Franklin Clark** as head of the Denver office of Cathodic Protection Service, 4601 Stanford, Houston 6. **Frank Dorr, Floyd Thorn** and **Jack Davis** have joined the Houston office and **John Search** is assigned to the Tulsa office of the company.

•

Robert Scheel has been appointed head of the Heil Process Equipment Corporation's Chicago office located at 400 W. Madison Ave.

•

Worcester Pressed Steel Co., Worcester, Mass., has named **John E. King** sales manager for the company.

•

W. D. Willes has been named product manager, Nordstrom Valves for Rockwell Manufacturing Co., 400 Lexington Ave., Pittsburgh 8. He succeeds **Orville W. Barnett** who has been appointed manager of the company's distribution and oil field sales.

•

M. H. Thornton has been named technical director of Midwest Research Institute, Kansas City, Mo.

•

American Cast Iron Pipe Co., Birmingham, Ala., has announced the retirement of its president **Charles O. Hodges.** He is succeeded by **Stephen D. Moxley. Arnold J. Herrmann** was named vice president and sales manager, **Frank H. Coupland,** vice president and works manager; **Kenneth R. Daniel,** vice president and chief engineer and **A. E. Bower,** treasurer for the company.

•

George B. Beitzel, president of Pennsylvania Salt Manufacturing Co., Philadelphia, will retire later this year.

•

J. L. Meem, Jr. has been appointed chief reactor scientist of the atomic energy products department, American Locomotive Co., Schenectady 5. **Robert D. Robertson** has been named materials engineer and **Harold Hoover** as process design engineer for the department.

•

Eugene P. Fager, vice president and director of Industrial Water Treatment Sales, Dearborn Chemical Co., Chicago, retired January 1.

•

Charles E. Kaufman has been appointed manager of the chemical product development department for Hagan Corp., 323 Fourth Ave., Pittsburgh.

•

Richard A. Mixer, corrosion engineer in the MW Protective Coatings Division of Metalweld, Inc., Scotts Lane & Abbottsford Ave., Philadelphia 29, has been named manager of that division.

•

William C. Sandland has been named sales representative for the Houston area for Reilly Tar & Chemical Corp., Green Bldg., 2009 Fannin, Houston.

•

Sheller L. Steinwender has been named vice president of The Permutit Co., 330 W. 42nd St., New York 36.

•

A. Craig Hood and **George E. Clauser** have joined the technical division of Superior Tube Co., Norristown, Pa.

•

George J. Hutzler has been appointed manager of Engineering Research for Spencer Kellogg and Sons, Inc., Buffalo 5.

•

Edward D. Flavin has been appointed vice president of Johns-Manville Sales Corp. and Manager of the Company's Special Industries, Industrial Products Division. He succeeds **L. A. Baldwin** who has retired after 35 years with the company.

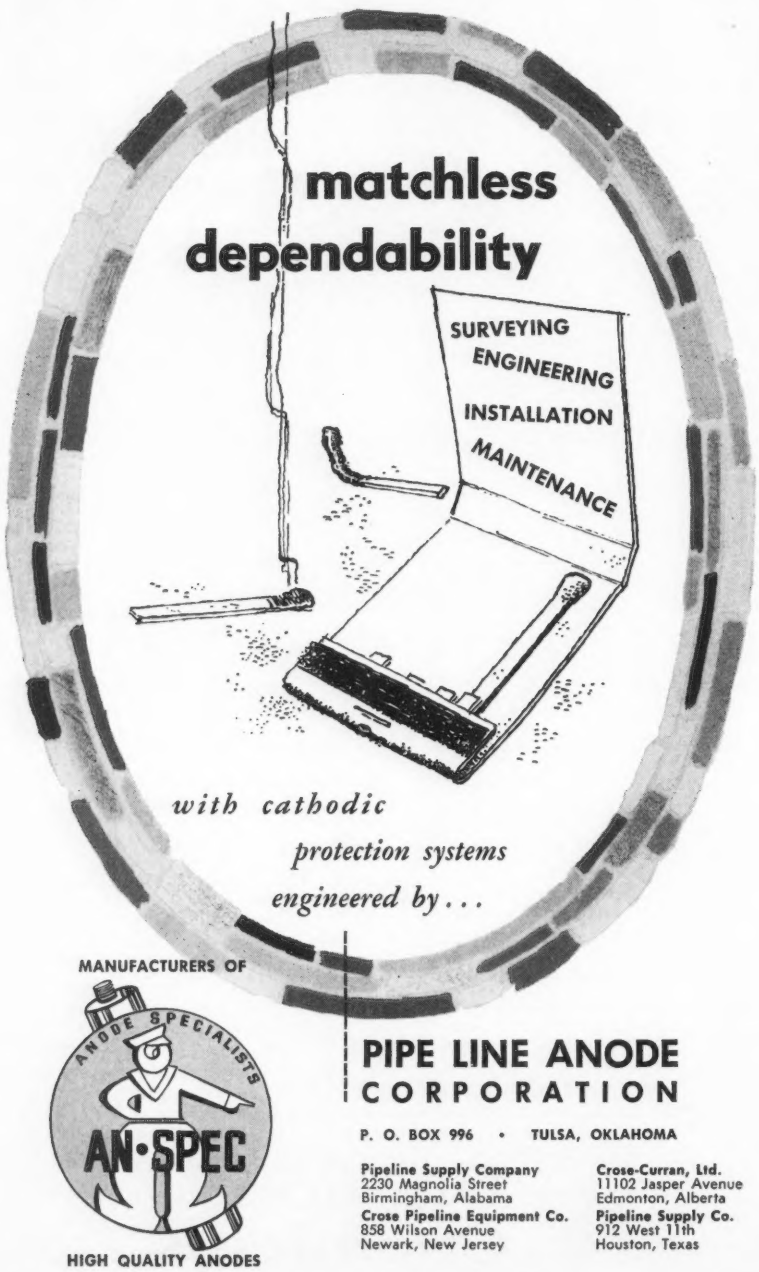
•

William L. Faith, deputy director of the Air Pollution Foundation, 704 S. Spring St., Los Angeles 14, has been named vice president and chief engineer of the organization.

•

Trevor G. Boyce has been appointed representative in Texas for the Taber Pump Co., 291 Elm St., Buffalo 3.

(Continued on Page 103)



PERSONALS

(Continued From Page 102)

Granville M. Read, chief engineer of E.I. du Pont de Nemours & Co., Inc., Wilmington, has been named to receive the American Society of Mechanical Engineers Medal. The award is presented annually for distinguished service in engineering and science.

•

Earl D. Gould has joined Rio Engineering Co., P. O. Box 6035, Houston, as project field engineer. He will specialize in cathodic protection of oil and gas well casing.

•

James A. Arter has been appointed vice president in charge of manufacturing for Ampco Metal, Inc., 1745 S. 38th St., Milwaukee 46. J. P Henry has been named general sales manager for the company. R. J. Stevenson succeeds Mr. Henry as assistant general sales manager for Ampco.

•

Hilton A. Levonian has been appointed vice president in charge of consulting engineering of The Kuljian Corp., 1200 N. Broad St., Philadelphia 21.

•

Glynn F. Martin has been elected vice president in charge of sales and **Loren B. Odell** vice president in charge of production for the James Bute Co., Houston.

•

Herman Francis Mark, director of the Polymer Research Institute at the Polytechnic Institute of Brooklyn, has been selected to deliver the annual Joseph J. Mattiello Memorial Lecture at the annual meeting of the Federation of Paint and Varnish Production Clubs scheduled at the Hotel Statler in New York, October 3-5, 1955.

•

John F. Haines, formerly vice president and chief engineer of the McCauley Industrial Corp. of Dayton, has been named chief development engineer, atomic products for the American Locomotive Co., Schenectady 5.

•

Charles W. Mullis and **M. A. Wolf** have been appointed assistant physicists of the Applied Physics Division of Midwest Research Institute, Kansas City, Mo.

•

George T. Deck, technical director at American Potash & Chemical Corporation's main plant at Trona, Cal., has been named plant manager of the American Lithium Chemicals, Inc. plant near San Antonio, Texas.

•

H. L. Stockdale has been named president of Insul-Mastic Corporation of America, 1141 Oliver Bldg, Pittsburgh 22. He was at one time manager of the Houston branch of the company.

•

George W. Lewis, Jr. and Howard S. Ring have been added to the staff of Climax Molybdenum Company's Detroit Laboratories. Dr. Lewis will be project engineer in charge of research on molybdenum corrosion inhibitors and Mr. Ring will work on molybdenum catalysts.

•

Edward Mackasek has announced his retirement as managing director of the Porcelain Enamel Institute, Washington, D.C., effective May 1. **John C. Oliver** will head the institute's staff operations under his present title of secretary.

Carl D. Burkland has been promoted to chief industrial engineer by Wheeling Steel Corp., Wheeling, W. Va.

•

L. S. Wilcoxson has been appointed vice president in charge of the Boiler Division of Babcock & Wilcox, 161 E. 42nd St., New York City.

•

Charles B. Sanborn has joined the Electroplating Section of the Development and Research Division, The International Nickel Co. Inc., 67 Wall St., New York 5.

•

Loran S. O'Bannon has been named technical adviser at Battelle Memorial Institute, Columbus, Ohio.

•

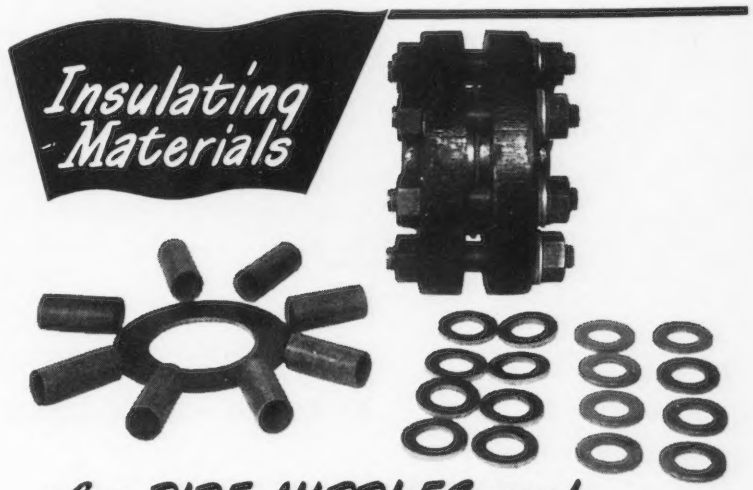
F. M. Watkins has been retained by the Division of Transportation of the American Petroleum Institute to coordinate research on corrosion problems. Employed by Sinclair Research Laboratories, Inc., Harvey, Ill., Mr. Watkins' relationship with API is that of employee on loan and he will ultimately return to Sinclair.

•

Hugh C. Land has been named to succeed **William P. Drake** as head of the Industrial Chemicals Division of Pennsylvania Salt Manufacturing Co., Philadelphia 7.

•

Chandler G. Lewis has been appointed assistant general manager of the Martins Ferry factory of Wheeling Steel Corp., Wheeling, W. Va. He has been with the corporation since 1939.



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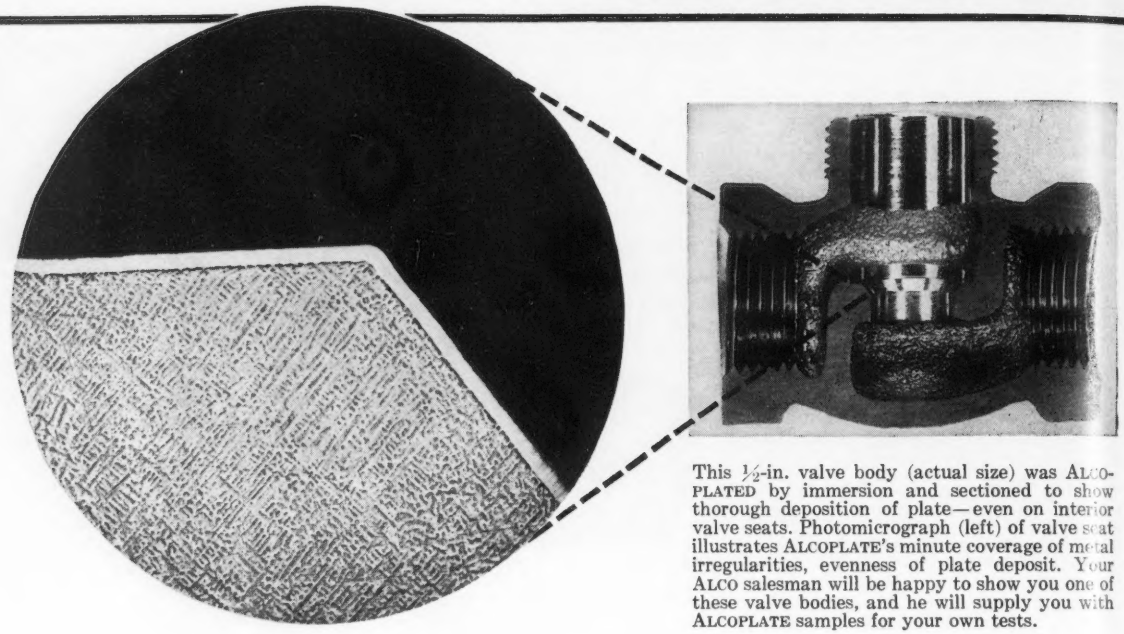

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Corrosion Abstracts

CORROSION CONTROL — PROTECTED INDUSTRY — NATIONAL ASSOCIATION OF CORROSION ENGINEERS

Index to CORROSION ABSTRACTS

Vol. 11 June, 1955 No. 6

3. CHARACTERISTIC CORROSION PHENOMENA — Page
3.7 Metallurgical Effects 105
4. CORROSIVE ENVIRONMENTS
4.2 Atmospheric 105
4.4 Chemicals, Organic 106
4.5 Soil 108
4.6 Water and Steam 108
5. PREVENTIVE MEASURES
5.2 Cathodic Protection 109
5.3 Metallic Coatings 110
5.4 Non-Metallic Coatings and Paints 112
5.6 Packaging 114
5.7 Treatment of Medium 114
5.8 Inhibitors and Passivators 114
5.9 Surface Treatment 116
5.11 Design-Influence on Corrosion 118
5.12 Metallurgical Treatment 118
6. MATERIALS OF CONSTRUCTION
6.1 General 118
6.2 Ferrous Metals and Alloys 118
6.3 Non-Ferrous Metals and Alloys—Heavy 118
6.4 Non-Ferrous Metals and Alloys—Light 122
7. EQUIPMENT
7.1 Engines, Bearings, and Turbines 123
7.3 Pumps, Compressors, Propellers and Impellers 123
7.4 Heat Exchangers 124
7.5 Containers 124
7.6 Unit Process Equipment 124
7.7 Electrical Telephone and Radio 124
8. INDUSTRIES
8.8 Group 8 126
8.9 Group 9 126

3. CHARACTERISTIC CORROSION PHENOMENA

3.7 Metallurgical Effects

3.7.3, 6.2.5

How Tempering Affects Corrosion Resistance of 12% Chromium Steel. A. SIMON. Crucible Steel Co. of America. *Materials & Methods,* **40,** No. 1, 138-139 (1954) July.

Effects of tempering Type 410 steel at 1000-1100 degrees F are loss of corrosion resistance and susceptibility to stress corrosion cracking. Several commercial heats of Type 410 were tested; compositions are tabulated. Data are presented showing relative amounts of rust in water vapor condensate at 100 degrees F.—INCO. 8268

3.7.4, 3.7.3

Effect of Microstructure on Corrosion. H. H. UHLIG. Paper before Am. Soc. Metals, Cleveland, October 17-23, 1953. ASM Relation of Properties to Microstructure, 1954, p. 189-208; *Trans. Am. Soc. Metals,* **46A,** 189-208 (1954).

Paper discusses the electrochemical theory of corrosion, the microstructure of steels and corrosion in acids, ringworm attack, the effect of cold work, and the effect of grain orientation on the rate of attack. The cracking of 9 percent nickel-iron alloy and the effects of microstructure in 18-8 stainless are used to illustrate principle relating microstructure to corrosion. Lattice structure, stress corrosion cracking and subgrain structure are also discussed. Data for the effect of heat treatment on corrosion of wrought austenitic and ferritic 18-8, and for magnetic induction and corrosion weight loss in nitric acid+hydrofluoric acid of austenitic 18-8 (0.007 percent carbon, 0.24 percent nitrogen) is presented. Ternary diagram for chromium-nickel-iron alloys at 650 degrees C is included. Tables, graphs, photomicrographs, 23 references.—INCO. 8245

3.7.4, 6.2.5

Effect of Sigma Phase on Properties of Alloys. A. J. LENA. *Metal Progress,* 66, No. 2, 94-99 (1954) August.

Magnitude of the effect which sigma may have on mechanical and corrosion properties of stainless steels depends not only on the amount present but also on particle size and distribution. General conclusions are given regarding effect on notch-sensitivity, ductility at room and elevated temperature, tensile strength and results of corrosion tests. Graphs and photomicrographs.—INCO. 8140

4. CORROSIVE ENVIRONMENTS

4.2 Atmospheric

4.2.3, 7.1, 5.3.2

The Problem of Scaling and Corrosion-Cracking in High-Temperature Gas Turbine Alloys. P. GALMICHE. *Recherche Aeronautique,* No 39, 45-53 (1954) *May/June.*

Investigation designed to determine the influence of chromium content (impoverishment or enrichment) in surface layers of high-temperature materials, in order to establish the causes and mechanism of corrosion-cracking in combustion gases. Alloys studied were Imphy ATGS, Nimonic 75, 80 (Per 2), 90 and 95, and Oneral (cobalt-chromium-base alloy for blades). Some of the specimens were chromium-enriched by means of chromizing according to O.N.E.R.A. process, while others had chromium removed from surface by means of high-temperature oxidation followed by electrolytic deoxidation. All specimens were electropolished. Full description of special testing equipment, conditions and technique is given. Data on behavior of Nimonic and Nimonic-type alloys, Oneral, iron, nickel, cobalt, 18/8 and Hastelloy B in combustion gases of kerosene, notes on deleterious influence of structural-hardening elements on resistance to cracking-corrosion, relationship between cracking-corrosion and combustion conditions, effects of sulfur, potentialities of chromium enrichment by diffusion as an answer to the problem of cracking-corrosion, and notes on possible application of metallic or ceramic coatings in this connection are discussed. —INCO. 8201

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4.2.3, 7.6.4

The Corrosive Nature of Combustion Gases. G. WITTINGHAM. *Corrosion Technology,* 1, No. 6, 182-187, 193 (1954) August.

Laboratory and field investigations on corrosion by flue gases from solid fuel combustion carried out by the British Coal Utilization Research Assoc. are outlined and the effects of different flue gas constituents on corrosion phenomena are discussed. Lab studies of the effects of fuel type and method of combustion on the sulfuric acid content of combustion gases are described. Results of measurements of the condensation characteristics of flue gases from water-tube boilers in power stations and from various industrial boilers and furnaces, and investigations into the use of additives are described briefly. Theoretical consideration of effects of fuel type, and burning rate on the amounts of sulfuric acid likely to be present in the combustion products from domestic appliances are considered. Tables, graphs and 28 references.—INCO. 8233

4.3 Chemicals, Inorganic

4.3.2

New Ideas for Handling Sulfuric. F. J. HENDEL AND H. B. PATEMAN. Wigton-Abbott Corp. *Chem Eng.,* **61,** No. 7, 209-210 (1954) July.

Economy dictated the use of straight carbon steel for tank and piping con-

struction, satisfactory for contact with sulfuric acid of better than 60 degrees Be. A breather line helps keep the system dry and decreases corrosion. Carbon steel was judged inadequate for valves and pumps because their construction makes them more vulnerable to corrosion. A special austenitic stainless steel with 24-30 percent nickel, 19-21 percent chromium, and 0.07 percent carbon was selected.—INCO. 8056

4.3.5

The Corrosive Effects of Fluorine. *Ind. Chemist,* **30,** No. 353, 266-268 (1954) June.

Summarizes available data on the corrosion resistance of materials of construction: steels, non-ferrous metals, organic and other non-metallic materials. Also fabrication of plant, and design of valves for service in fluorine. Eight references.—BNF. 8156

4.3.5, 8.3.1

Liquid Fertilizers—Vast New Market for Aluminum Equipment. J. Staley. Reynolds Metals Co. *Modern Metals,* **10,** No. 7, 44, 46, 48 (1954) August.

Revolutionary use of liquid nitrogen fertilizers calls for aluminum equipment because of its light weight, low cost and superior corrosion resistance. Aluminum is superior to steel, copper, zinc, brass, bronze, Monel and galvanized steel. Ordinary steels and cast iron are rapidly corroded by these solutions, forming scales and sludges. Even small parts or trim materials of copper, zinc, brass, bronze, Monel or galvanized metals should be avoided. A disadvantage of steel equipment is the safety hazard while attempting repair; encrustations of nitrate materials are difficult to remove whereas aluminum equipment can be thoroughly cleansed by streams of water.—INCO. 8261

4.4 Chemicals, Organic

4.4.6

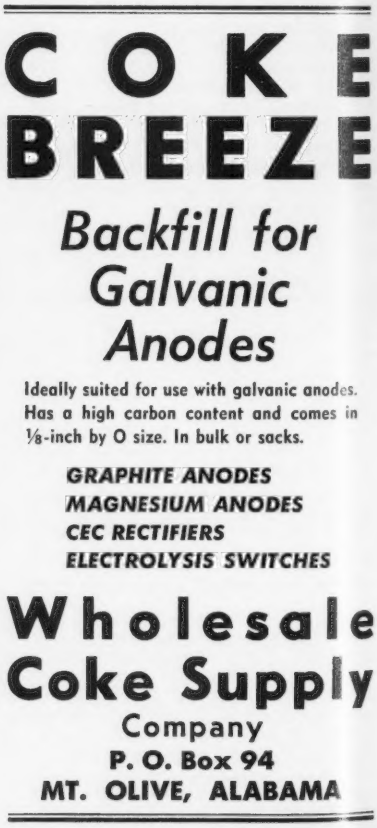
Corrosion of Metals by Saturated (Hydrocarbon) Fuel. (In Russian). I. N. Putilova, L. G. Gindin and E. V. Artamonova. *Doklady Akad. Nauk. S.S.S.R.,* **94,** No. 3, 489-492 (1954) January 21.

Corrosion tests on various steels, magnesium and two magnesium alloys (Elektron MA-1, containing 2.2 percent manganese, 0.3 percent aluminum, 0.3 percent zinc, 0.23 percent silicon, etc.; and Elektron MA-5, containing 8.3 percent aluminum, 0.7 percent zinc, 0.3 percent manganese, 0.2 percent silicon, etc.) in both moist and dry kerosene. Also, investigation of the attack at the boundary between layers of kerosene and water or sodium benzoate solution. —BNF. 8294

4.4.6, 7.1

Metallic Elements in Fuel Oils. F. H. Garner, S. J. Green, F. D. Harper and R. E. Pegg. *J. Inst. Petroleum,* **39,** 278-293 (1953) May.

Deposition of ash and corrosion, both major difficulties in the use of residual fuels in gas turbines are due mainly to vanadium and sodium in the oil. Iron sodium, vanadium and nickel are the chief metals present in an Iraq residue examined and methods have been developed for the determination of these elements in oils. Iron and sodium compounds can be removed by filtration and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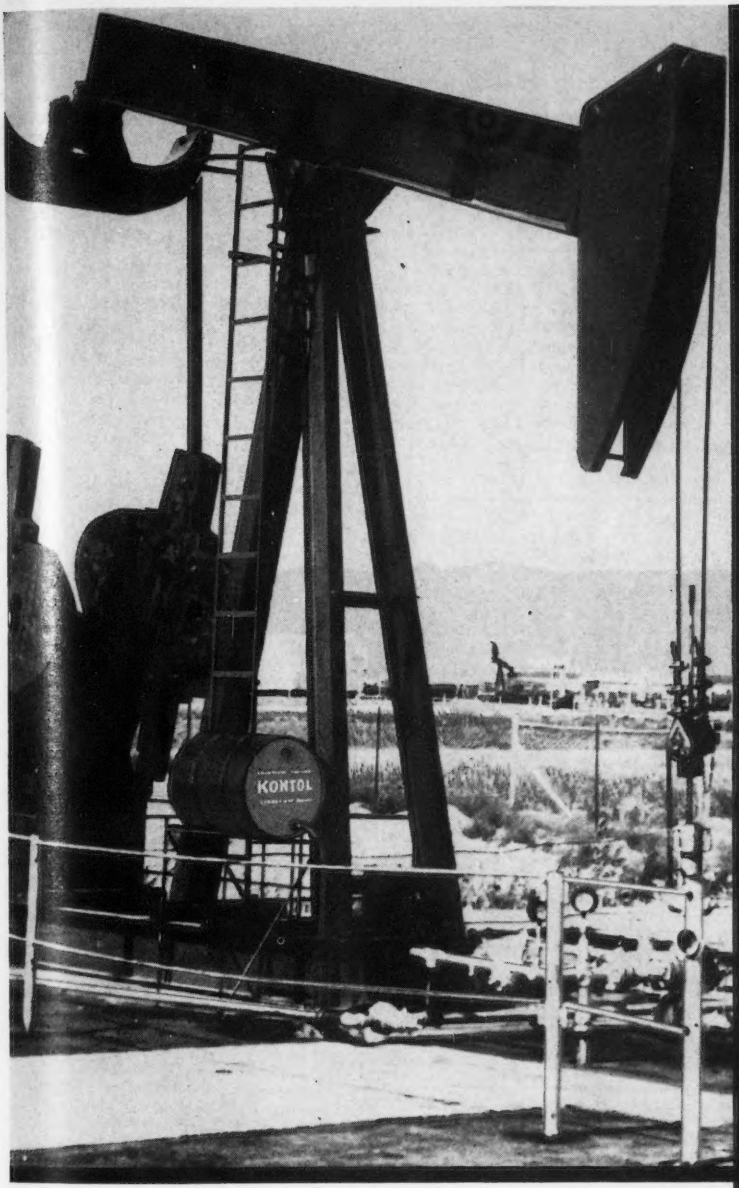

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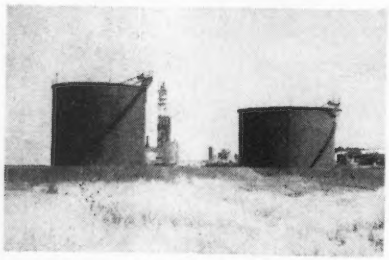

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water-washing respectively but vanadium and nickel compounds cannot be removed by simple means and are present as organic compounds dispersed in the oil. Adsorbent and solvent extraction have been found to concentrate the vanadium compounds but by both methods the maximum for an Iraq oil was only fourteen times that of the original fuel oil, viz. 0.07 percent vanadium. Both vanadium and nickel compounds could be concentrated in a fraction representing about 5 percent of the Iraq crude used and in about 20 percent of a Venezuelan crude and they are combined with a significant part of the asphaltenes. Previous work suggesting that all the vanadium is present as porphyrins is criticized. No method was found of preparing fuel oils free from vanadium which would be cheaper than distillation.—TIME. 8343

4.5 Soil

4.5.1, 5.2.2, 1.7.1

Maintenance Aspects of Corrosion Program at Fairless Works. K. L. Johannsen. U. S. Steel Corp. *Iron Steel Engr.*, **31**, 115-121 (1954) Sept.

U. S. Steel Corp.'s program of corrosion control and education is described. Initiating of field surveys on existing above-ground and underground installations was emphasized. Metals that present the most concern in underground corrosion problems are steel and lead, but if these metals are kept dry or the earth current stray is eliminated, corrosion will be greatly retarded. All copper grounding rods and bare copper wires are eliminated. All magnesium and steel ground rods are cadweld, connected with neoprene covered and taped copper cables, thus reducing sources of galvanic corrosion. Magnesium is buried in a definite pattern near the steel ground rods to protect them. Ground beds are clearly marked. All underground steel pipe is given a protective coating of tar compounds and wrapping before installation. Corrosion maintenance program is also described. Tables, diagrams and six references.—INCO. 8366

4.6 Water and Steam

4.6.1

Treatment of Water for the Iron and Steel Industry. A. J. Lamb and A. H. Waddington. *J. Iron Steel Inst.*, **176**, 291-302 (1954) March.

Types of water usually available; treatment necessary to make them suitable for particular purposes; design of plant used to effect treatment; chemical reagents more commonly used; and plant control. Photographs, diagrams.—BTR. 8130

4.6.1, 2.3.4, 6.4.2

The Absorptiometric Determination of Traces of Copper in Highly Purified Water. E. N. Jenkins. *Analyst*, **79**, No. 937, 209-216 (1954) April.

Determination of as little as 0.001 ppm copper as cupric diethyldithiocarbamate. The method should be of use in the control of the pitting corrosion of aluminum. The author mistakenly says that the U. S. Public Health Service recommends that copper concentration in drinking water should not exceed 0.2 ppm; in point of fact the latest U. S. Public Health Service Drinking Water Standard indicates only that waters containing more than 3 ppm of copper should not be used if a more satisfactory supply is available.—BNF. 8269

4.6.1, 7.2

Mechanism of the Internal Corrosion of Water Pipe. Rolf Eliassen and James C. Lamb, III. *J. Am. Water Works Assoc.*, **45**, 1281-1294 (1953) Dec.

Discusses effects of several variables. Outlines requirements for further research. Diagrams, graphs, tables. 9 references.—BTR. 8363

4.6.1, 7.2

The Control of Corrosion. R. S. Weston. *Water & Sewage Works*, Pt. 2, **101**, No. 5, R141-R144 (1954) May.

Correction and control of corrosion in water pipes by use of soda ash, lime, silicate of soda, and Calgon, and use of cathodic protection, are discussed. Graphs and 5 references.—INCO. 8234

4.6.1, 8.4.3

Prevention of Corrosion by Water in Oil Refineries. Peter W. Sherwood. *Corrosion Technology*, **1**, No. 4, 113-115, 120 (1954) June; *Werkstoffe u. Korrosion*, **5**, No. 5, 168-172 (1954) May.

Prevention of corrosion by water is the most important item of preventive maintenance in petroleum refineries. This problem is encountered in innumerable forms and no one solution satisfies all the requirements of a single refinery. Broad field of protection from water corrosion takes in underground storage tanks which are to be spared attack from soil water, prevention of corrosion in heat exchangers due to sweet or brackish cooling water, and protection of exposed metallic structures from rain water. Cathodic protection, metallic coatings, organic coatings, inhibitors, alteration of environment and metallurgical selection are major methods of corrosion control.—INCO. 8293

4.6.2, 7.6.4, 5.8.2

Evaluation of Several Alkaline Compounds for Controlling Corrosion-Erosion in Boiler Feedwater Systems. J. M. Decker and J. C. Marsh. Detroit Edison Co. Paper before Am. Power Conf., Chicago, March 24-26, 1954. *Proc. Am. Power Conf.*, **16**, 569-576, disc. 576-579 (1954).

Evaluation of ammonia, cyclohexylamine, morpholine and sodium hydroxide for controlling corrosion-erosion in boiler feedwater systems. Specimens of chromium-molybdenum steel, carbon-steel, carbon-molybdenum steel, Admiralty brass, copper-nickel (70:30 and 90:10), Monel and cast carbon-steel were subjected to the action of feedwater at Marysville Power Plant in a test apparatus used for earlier corrosion-erosion tests. Results showed that ammonia reduced the rate of attack of ferrous metals but not of the nonferrous. Sodium hydroxide reduced rate of attack on all metals. Cyclohexylamine had same effect as ammonia, while morpholine did not reduce rate of attack of any of the metals. Diagrams, tables, graphs and 10 references.—INCO. 8085

4.6.4

Water Treatment for Cooling Towers. W. J. Winzig. *Blast Furnace Steel Plant*, **42**, No. 7, 812-816 (1954) July; *World Oil*, **138**, No. 5, 261-264, 266 (1954) April.

Cooling system problems usually encountered are: corrosion of metal surfaces; inorganic scaling due to calcium carbonate, calcium sulfate, magnesium compounds and iron oxides; organic growths such as algae and bacterial

slime; and delignification of the wood in the tower. Corrosion may be minimized by using chemical inhibitors such as polyphosphates, silicates or chromates which form protective films on the metal surfaces. Scale preventive procedures are softening, alkalinity reduction, surface active treatment, and deconcentration. Bacterial growths can be prevented by the use of biochemical poisons, most effective of which is chlorine. Maintenance of circulating water pH below 8.3, together with the use of a fungicide, has proved to be a successful method of controlling delignification. Tables, graphs.—INCO. 8277

Right Water Treatment Extends Cooling-Tower Life, Saves Money. J. M. SLOUGH. Santa Fe Tank & Tower Co. *Power*, **98**, No. 5, 100-101, 232, 234, 236, 238 (1954) May.

Review of chemicals added to cooling-tower water to control scales, delignification, corrosion, and algae and slime. Passivators for corrosion control include chromates, silicates, phosphates, chromolucosates, glucosides and sodium-sulfoglucosates. Bacteria causing corrosion are controlled by residual chlorine, and soda-lime.—INCO. 8241

4.6.8, 8.10.3

Prevention of Water Corrosion in Mining Operations. P. W. SHERWOOD. *Can. Mining J.*, **75**, No. 8, 72-75 (1954) August; *Mining Mag.*, **90**, 275-280 (1954) May.

Mining industry encounters corrosion by water in all of its forms. Impurities, temperature, and velocity, three of the important influences affecting the corrosive action of water, are discussed. Six methods of reducing this corrosive action, including cathodic protection, metallic coatings, organic coatings, inhibitors, alteration of environment, and metallurgical selection, are suggested.—INCO. 8301

4.6.13, 6.3.6, 2.2.3

The Corrosion of Copper Tube used in Soil-Stack Installations. H. E. BABBITT, E. R. BAUMANN AND H. N. HAYWARD. *University of Illinois Bulletin* (Eng. Expt. Sta. Bull. Series No. 419), **51**, No. 17, 42 pp. (1953) October.

A study of the effect of sewage on copper tube in soil stacks. Sewage was pumped either continuously or intermittently through the stacks. The weight loss and change in electrical resistance of removable test pieces was measured monthly for five years. The rate of attack decreased with time, especially in the intermittent flow stack. The copper concentration in sewage from the intermittent flow stack was nine times as much as from the continuous but the weight loss from the latter was greater since the rate of flow of sewage was much greater. Corrosion was fairly uniform, reaching a depth of approximately 0.01-inch in five years. Addition of detergent had no effect on the corrosion. —BNF. 8335

5. PREVENTIVE MEASURES

5.2 Cathodic Protection

5.2.1, 2.3.5, 3.2.2

Some Observations of Cathodic Protection Potential Criteria in Localized Pitting. A Report of T-2C on Minimum Current Requirements for Cathodic Protection. L. P. SUDRABIN, Chairman. *Corrosion*, **10**, No. 8, 232-236 (1954) Aug.

In order to help understand the meaning of potential measurements protective current was applied to a model cell including the basic spatial, electrical and environment factors found in localized pitting. Corroding medias having a specific resistivity of 15,000-22,000 ohm-cm and 160 ohm-cm were used in the experiments.

The open circuit potentials of the anode and cathode elements including that of mill scale were observed. Equipotential lines measured in the corroding media are graphically shown for the coupled pitting system.

Equipotential lines are also graphically shown when protective current was applied and the corrosion current flow from the pit had ceased. It is noted that the equipotential line corresponding to the open circuit potential of the anode is located at some distance from the cathode. The DC null potential measurement technique was used to ob-

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serve any relation between a break in the potential-log current relation and the flow of corrosion current in the pit.

The following observations seem to have support: 1). The potential measurement of the cathodically protected structure should include all the IR drop form characteristics of polarization resulting from the flow of the protective current through the cathode resistive element. The latter resistive element includes the cathode surface resistance plus the resistance of the electrolytic cell adjoining the cathode surface. a). The boundary of the cathode electrolytic resistive element at which the reference electrode should be positioned seems to be determined by the size and spatial positions of the anode and cathode of the corroding system. The smaller the anode the closer the reference electrode should be placed to the structure. b). The location of the reference electrode becomes more important as the environment resistivity increases. 2). The ratio of protective current required to corrosion current increases with increasing media resistivity. 3). Mill scale can be more cathodic than copper. 8399

5.2.1, 8.4.3

Cathodic Protection and Control of Corrosion in the Middle East. W. C. R. WHALLEY. Paper before Society of Chemical Industry, Corrosion Group, London, November 13, 1953. *Chemistry & Industry,* No. 6, 140-147 (1954) Feb. 6.

Cathodic protection in the Middle East is confined at present to petroleum installations. Soil corrosivity in relation to climate and topography is discussed. Rectifiers, generator sets, galvanic anodes, and ground beds are considered, and cathodic protection of buried pipelines, tank farms and pump stations, submarine loading lines, and jetties and buoys are described. Illustrations and references.—INCO. 8238

5.2.1, 8.9.3

Eight Uses for Insulating Joints. A. W. PEABODY. *Gas Age,* **113,** 25-30, 75-81 (1954) May 6.

Corrosion protection in gas distribution. Diagrams.—BTR. 8282

5.2.1, 8.9.5, 7.10

Cathodic Protection of Ships and Marine Structures. K. A. SPENCER. Paper before Soc. Chem. Ind., Corrosion Group, Glasgow, March 5, 1954. *Chemistry & Industry,* No. 25, 702-708 (1954) June 19.

History and theoretical purpose of cathodic protection are described. Use of cathodic protection for active and for inactive ships is discussed. In the case of active ships, the anodes are firmly attached to the hull, but electrically insulated from it. Hull interiors cannot be protected unless an electrolyte is present, so nothing can be done to prevent corrosion by "sweating" inside the hull. Advantages of cathodic protection for marine structures, floating docks, jetties and piers, sheet piling, and buoys and pontoons are described. Diagrams, tables and 15 references.—INCO. 8381

5.2.2, 4.4.6, 8.9.5

Cathodic Protection of Cargo Spaces in Oil Tankers. J. LAMB, E. V. MATHIAS AND W. G. WAITE. *Trans. North East Coast inst. Engrs. & Shipbuilders,* **70,** Nos. 6 & 7, 377-408, D129-D140, (1954) March/April, May/June.

A detailed report of a 12 months experiment in the cathodic protection of one-third of the tanks of the 12,250-ton d.e.s. "Auris," which had previously been engaged for five years in carrying white oil (refined petroleum). During the trial 9 different cargoes, ranging from gas oil to high-octane aviation spirit, were carried; there were also periods when the protected tanks were in ballast or empty. Four magnesium alloys (S.A.S., S.A.U., C.S., and C.U.) were used as anodes, the standard material (S.A.S.) proving the most successful. It is estimated that corrosion was reduced by about 75 percent and that an expenditure of £50,000 on cathodic protection would save £250,000 in repair costs. About 60 tons of previously formed scale was shed from the tanks.—BNF. 8153

5.2.2, 8.9.3

Magnesium Anodes Protect Aransas Bay Flow Lines. W. A. JOHNSON Corrosion Rectifying Co. *World Oil,* **138,** No. 7, 246, 248, 250 (1954) June.

Cathodic protection of flow lines laid in salt water and moist land. A description of layout of magnesium anodes in the Blind Pass Field, Aransas Bay is given. Tests were conducted to determine how much corrosion would occur and how it could be halted by cathodic protection. Factors determining the amount of cathodic current required are length and diameter of line, type and effectiveness of coating, corrosiveness of water or soil, and interference effects. Maps, photographs.—INCO. 8143

5.2.3, 6.2.2

High-Silicon Cast Iron Tested for Use with Impressed Currents. WALTER A. LUCE. *Corrosion,* **10,** No. 9, 267-268 (1954) Sept.

Laboratory and field tests with high-silicon cast iron anodes in fresh and salt water and in earth indicate the material has promising characteristics for use as anodes in cathodic protection systems using external current sources. The material tested, Duriron, has 14.5 percent silicon. Low consumption rates at various current densities in the media listed were reported. 8147

5.2.3, 8.9.3, 3.6.9

Ashland Line Capacity Raised from 16,500 to 30,000 Bbl. Daily. R. F. DELANEY AND J. E. BROOKS. Ashland Oil & Ref. Co. *Oil Gas J.,* **53,** No. 20, 236-240 (1954) Sept. 20.

Purpose of field investigation of entire pipeline was to obtain data suitable to design a corrosion-mitigation system. On the basis of the tests, six rectifier units were installed at equal intervals along the pipeline. Protection realized from the rectifiers did not meet expectations as a large amount of the rectifier current was lost to foreign structures which required bonding to the pipeline to prevent stray-current damage. This problem is being worked on.—INCO. 8084

5.3 Metallic Coatings

5.3.4

Stop-Offs in Hard Chrome Plating. A. W. LOGOZZO. *Metal Finishing,* **52,** No. 5, 56-60 (1954) May.

Uses, advantages and techniques for lead foil, plastic sheet, adhesive tape and wax as stop-off materials.—BNF. 8126

5.3.4

Barrel Plating Considerations. E. E. HALLS. *Prod. Fin.,* **7,** No. 2, 61-72, 112 (1954) Feb.

Type and size of barrel, materials of construction, anodes, cathode contacts, electrolytes and maintenance of electrolyte, work load, current, current density and plating distribution are considered. —BNF. 8112

5.3.4

Cleaning and Preparation of Metals for Electroplating. Part VIII: Effect of Oxide Films. A Survey of the Literature. H. B. LINFORD AND D. O. FEDER. *Plating,* **41,** Nos. 3 & 4, 279-286, 397-401 (1954) March, April.

Literature survey summarizes previous work on the effect of electroplating onto oxide soiled basis metals. Methods by which oxide films are formed, and some of their characteristics, are examined. Mechanism of metal deposition, crystal formation, and adhesion are considered. Interfacial phenomena occurring during the plating process onto an oxide-soiled metal surface are interpreted. Effects of these processes and of the films themselves on the end product, the electroplate, are evaluated. Effect of films on the adhesion of electrodeposited nickel to nickel is tabulated. Qualitative tests of adhesion of chromium to nickel-plated brass, to steel, and to chromium are given. Tables and 115 references. This is part of the American Electroplaters' Society Research Project No. 12. 8372

5.3.4

Stainless Steel Linings as Protection Against Corrosion. H. G. GEERLINGS. Paper before 5th Symposium on Materials of Construction for the Chemical Industry (Clad Materials), sponsored by Dutch Chemical Soc. and Royal Dutch Inst. Eng., Nov., 1953. *Ingenieur,* No. 16, 18, 20-22 (1954); *Chem. Tech.,* No. 4-7, 33-39; disc., 39-40 (1954).

Describes various methods for lining vessels. Influence of type of welding rod on structure of weld metal is illustrated by Schaeffler diagrams. Data are given from tests carried out to establish influence of width of strips in strip lining. Steels considered are 14 percent chromium, 18/8 and 19/10/3.25 chromium-nickel-molybdenum.—INCO. 8380

5.3.4

Bright Nickel Process Simplifies Bumper Manufacture. R. D. MILLER Electric Auto-Lite Co. *Products Finishing,* **18,** No. 9, 24-30, 32 (1954) June.

Automobile bumpers manufactured by the Sharonville Div., Electric Auto-Lite Co., receive a heavy nickel plate to serve as a base for the final brilliant chromium plated finish. Bumpers are formed from steel sheets. Recently, a final bright nickel plating cycle was added to the plating process, and a light nickel "wiping" operation was substituted for the nickel buffing. Change produces a better bumper, and makes possible better utilization of the available nickel. Process which consists of a multiple plate has the advantage of blocking off and reducing the "thru-porosity" of the plate and improving its corrosion resistance. Illustrations.—INCO. 8175

5.3.4

Platers' Forum. *Metal Ind.,* 84, No. 7, 127-128 (1954) February 12.

The article contains a selection of questions and answers submitted at the Practical Platers' Forum held by the Midland Centre of the Institute of

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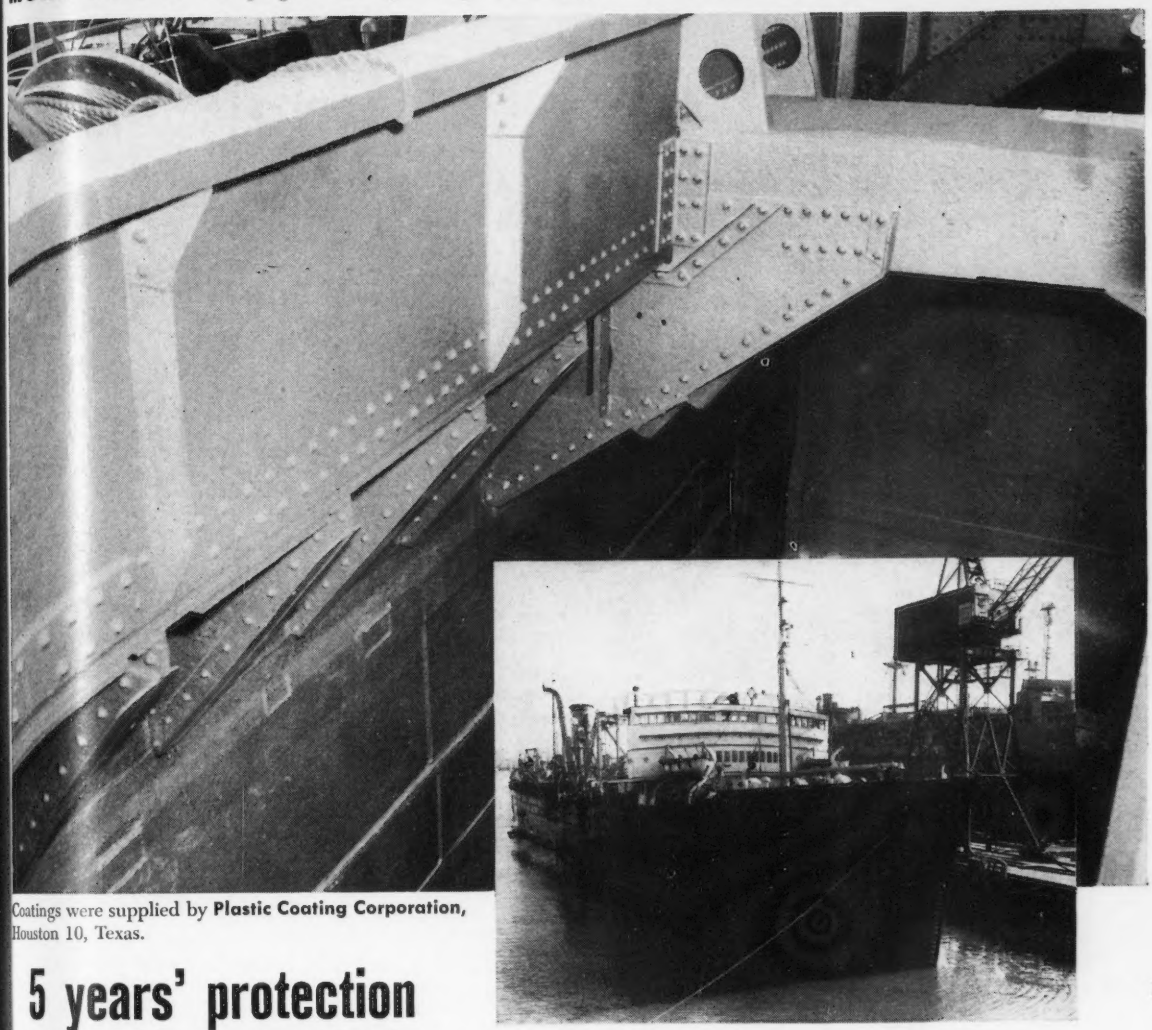

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Metal Finishing. Among the questions considered were: direct nickel versus copper-nickel; bright nickel plating; effectiveness of the jet method of testing nickel-plated articles; re-cast nickel anodes; and new chromium plating solutions.—ZDA. 8174

5.3.4

Spraywelding: A Modern Hard Facing Technique. S. M. HOLGATE. *Electroplating*, **7**, (Metal Spraying Section, **4**) No. 6, 239-242 (1954) June.

Parts to be hard faced are sprayed with nickel-chromium-boron alloys (Colmonoy Nos. 4, 5 and 6) in powder form, and the sprayed layer is remelted using an oxyacetylene torch; controlled atmosphere furnaces or induction heating are used for large scale production. Preparation, spraying and remelting of the coating; props., esp. protection against severe abrasion or corrosion; and applications.—BNF. 8212

5.3.4, 2.4.3

Works Control Thickness Tests in Metal Spraying. (In German). H. REININGER. *Metalloberflache*, Sec. A, **8**, No. 4, A55-A61 (1954) April.

After brief mention of other methods, the magnetic method of test is described, with examples of its use, statistical control, and application to control of spraying technique.—BNF. 8320

5.3.4, 5.12

1) The O.N.E.R.A. Chromizing Processes and the Heat Treatment of Chromized Materials. 2) Integrated Chromizing: Combined Heat-Treatment and Thermochemical Cementation with Chromium. P. GALMICHE. Papers before Journees d' Automne, October, 1953. 1) *Rev. met.*, **51**, 489-497 (1954) July. 2) *ibid.*, **51**, 498-501; disc., 501-502 (1954) July.

1) Review of principles of the processes, with description of industrial installations. Modifications to produce thick diffused corrosion-resisting coatings or thin layers of very hard chromium carbides, specific problems connected with thermal chromizing of steels, relationship between quality of steel and conditions of treatment on degree of protection conferred, and protection of copper-base materials (use of intermediate electrodeposited nickel layer: data on nickel-plated and chromized aluminum bronze) are discussed. Chromized surfaces are a basis for subsequent electrolytic chromium coatings.

2) Gives examples of cases in which surface-diffusion treatment, especially chromizing, may be combined with heat-treatment in a single operation. These relate to chromized sintered iron (details of technique for production of corrosion-resisting and hard coatings); and treatment of high-temperature materials to produce increased oxidation-resistance and to improve resistance to corrosion-cracking (80/20, 18/8, Hastelloy B, iron, nickel, cobalt). Special reference to behavior of 80/20 in contact with combustion gases of kerosene is made. In this section, reference is made to an article dealing with chromium content (impoverishment or enrichment) in Nimonic alloys, which appeared in *Recherche Aeronautique*, May/June, 1954 by author. Other potential applications are indicated.—INCO. 8225

5.4 Non-Metallic Coatings and Paints

5.3.4, 7.7

Metallising (Non-Conductors) with an Aqueous Platinic Chloride Solution. L. SILVERMAN AND K. TREGO. *Metal Finishing*, **52**, No. 4, 69 (1954) April.

Preferred reducing agent is hydroxxylamine hydrochloride solution may be made up from scrap platinum and applied to many shapes of aluminum oxide, porcelain, ceramics, silicaware, quartz and etched Pyrex. Adherent electrical conducting coating of pure platinum is obtained which has corrosion resistance superior to that of silver usually employed. One special use of process is for mullite tubes for shielding thermocouple wire, which are made impermeable to carbonaceous gases by metallizing with platinum, then plating with rhodium.—8243

5.4.2

Applications of Barrel Enamelling. W. S. FIELD. *Prod. Fin.*, **6**, 52-55 (1953) October.

Discusses field of application and costs. Photographs.—BTR. 8369

5.4.2, 3.8.4

Galvanic Corrosion Theory for Adherence of Porcelain Enamel Ground Coats to Steel. D. G. MOORE and others. *J. Am. Ceram. Soc.*, **37**, No. 1, 1-6 (1954) January.

Experiments on the corrosion during firing of enamels on iron/copper, iron/-cobalt, iron/nickel, iron/beryllium and iron/gold couples. Some evidence for the galvanic corrosion theory (for explaining the function of cobalt in ground-coat enamels) was obtained, but there are certain inconsistencies.—BNF. 8170

5.4.2, 6.4.2

Low Temperature (Vitreous) Enamels and Their Application to Aluminium. *Ind. Finishing*, **6**, No. 70, 630-634 (1954) April.

A survey of the present position, including compositions, methods of application, etc.—BNF. 8158

5.4.3

Making and Using Glassed Steel Vessels. *Can. Chem. Processing*, **37**, 54, 56, 58 (1953) March.

Describes construction details and presents corrosion-resistance data. — BTR. 8392

5.4.3, 7.2, 8.9.3

Plastic Liners for High-Pressure Pipelines. R. G. DEERING. *Oil Gas J.*, **53**, No. 6, 120-122 (1954) June 14.

Thin-wall plastic butyrate tubing lines high-pressure pipes to prevent internal corrosion. A Kewanee Oil Co. pipeline, 2400 feet, was completely lined. Hydrogen sulfide and salt water are the corrosive agents dealt with in lines carrying highly corrosive formation water. Construction procedure is described. Photographs.—INCO. 8081

5.4.3, 8.8.1

Rubber Linings Protect Plant in New Bromine Factory. *Corrosion Technology*, **1**, No. 4, 111-112 (1954) June.

Corrosion-resistant rubber lining was used in the new bromine-from-sea-water plant on the Isle of Anglesey, North Wales. In addition a large amount was used for pipes, valves, ducting and jointing material. The rubber lining work carried out in this unusual chemical plant, the products of which are used to make tetra-ethyl lead anti-knock compounds for aviation and motor fuel is described.—INCO. 8076

5.4.5

Why Go to Thick Protective Coatings? R. R. PIERCE. Penn. Salt Mfg. Co. *Chem. Eng.*, **61**, No. 4, 177-179, 181 (1954) April; *Werkstoffe u. Korrosion*, **5**, No. 1, 1-4 (1954).

Data on performance of five basic types of coatings, including vinyls, chlorinated rubbers, oil-base paints, neoprenes and chlorinated aliphatic hydrocarbons of various thicknesses in six industrial hydrochloric acid atmospheres, are given. Results show that under five mils. thickness, failure of equipment will be rapid regardless of coating type due to poor coverage over hard-to-coat areas. Above five mils., coating performance can be controlled and it depends primarily on resistance to the environment of the coating selected. Graphs and three references.—INCO. 8252

5.4.5

Recent Developments in Silicone Vehicles for Maintenance Paints. R. C. HEDLUND. *Org. Finishing*, **15**, 16-18 (1954) February.

Fast drying silicone-vehicle, silicone-alkyd co-polymer, and modified silicone-alkyd resins. Photographs, tables. — BTR. 8058

5.4.5

Application Techniques, Physical Characteristics and Chemical Resistance of Polyvinyl Chlor-Acetates. R. McFARLAND, JR., Chairman. A Report by Unit Committee T-6A on Organic Coatings and Linings for Resistance to Chemical Corrosion. *Corrosion*, **10**, No. 10, 349-354 (1954) October.

The report consists of a tabulated sched-

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ule of data plus a narrative report amplifying the information in the table. Consideration is given in an introduction to general considerations affecting organic barriers with respect to surface preparation, principal reasons for failures, application techniques, design factors and testing.

The body of the report specifically about polyvinyl chlor-acetates summarizes properties, discusses compounding variations, resistance to water, inorganic acids; oxidizing conditions, alkalies, salt solutions, temperature limitations, impact and abrasion resistance, hardness, aging characteristics, toxicity, weight of coatings vs. thicknesses, electrical properties, coverage and shipping data, flammability and toxicity, surface preparation and application methods. 8116

5.4.5

Film Thickness for Adequate Protection. E. V. GOLDSTEIN. *Ind. Finishing* (USA), **29**, No. 10, 118-119 (1953).

The additional protection afforded by thicker coatings is emphasized; e.g., a 0.8×10^{-3} inch coating failed in 72 hours in a salt spray test and in more than 300 hours when the thickness was increased to 2×10^{-3} inch.—RPI. 8365

5.4.5, 2.1.2

Volume Relations in Coating Films. J. BUNDIES. *Deut. Farben-Z.*, **7**, 177-178 (1953); *Chem. Abs.*, **47**, No. 16, 8389 (1953) August 25.

When the swelling in water of rust-preventive coatings is discussed, the results differ greatly depending on whether they are expressed on the basis of the film weight, the film volume or the vehicle weight. The article quotes the example of the different results obtained by three methods when comparing water adsorption by Pb_3O_4 (specific gravity of film 4.0) and zinc chromate (specific gravity of film 1.6). It concludes by saying that results comparing pigmented films on the basis of their weight alone present a distorted picture.—ZDA. 8333

5.4.5, 4.2.3

New Automotive Uses for Silicones. *Automotive Inds.*, **109**, No. 9, 113-114 (1953) Nov. 1.

Silicones or modified silicone resins may be used, together with aluminum flake, powdered zinc or other heat-stable pigments in the production of heat and weather resistant paints, lacquers and enamels. Such coatings have been used on exhaust manifolds, which retain their freshly painted look after long periods of engine operation and also protect the brake drums of convertible and sport cars fitted with wire wheels.—ZDA. 8348

5.4.5, 4.2.3, 4.4.7

New Aircraft Coating for Corrosion Prevention. M. W. LARSON. *Aviation Age*, 21, 62-65 (1954) Feb.

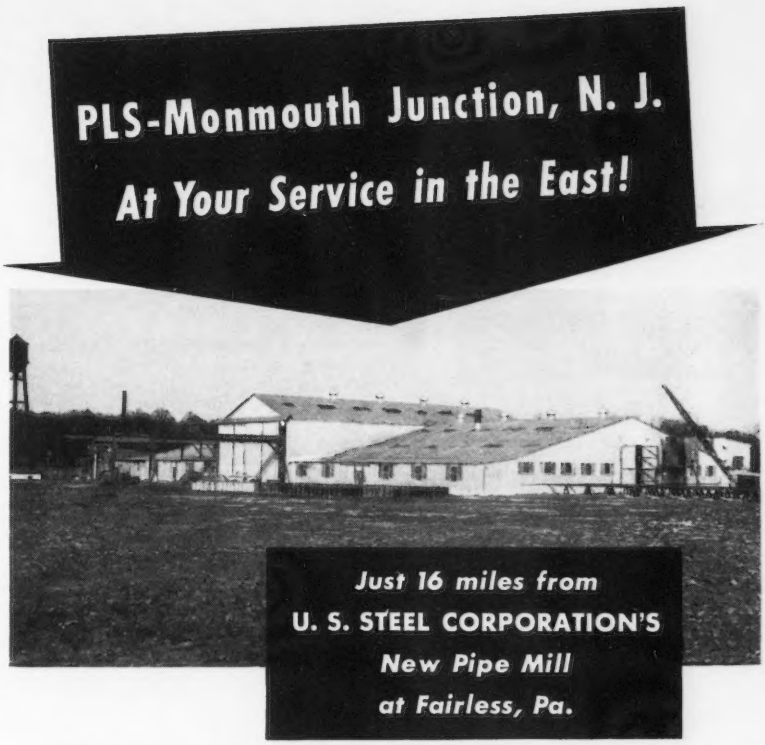
Epoxy resin paint developed to give resistance to Skydrol hydraulic fluid was found to be an excellent protective coating for use in exhaust path areas as well. Tables, graphs.—MR. 8152

5.4.5, 6.4.4

Wash Primers for Magnesium. *Am. Paint J.*, **37**, No. 22, 76-84 (1953).

Standard wash primers cause blistering of the paint film.

Reduction of the phosphoric acid content to 25% of the resin gives satisfactory results. The use of chromium phosphate pigment is discussed.—EL. 8384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5.4.7

Flame Spraying Ceramics. T. A. DICKINSON. *Prod. Fin.*, **18**, No. 5, 32, 34, 36 (1954) Feb.

Technique consists of pneumatically ejecting fine refractory powders through flame with spray gun used for metallizing purposes; method expected to permit application of heat resistant ceramic coatings on materials like aluminum, magnesium and titanium as well as iron and steel products. Spray-gun developed by Schori Process Division of Ferro-Co. Corp., New York; process developed by Ryan Aeronautical Co. 8087

5.4.10, 8.9.3

Installing a Large Diameter Products Pipe Line Through a Heavily Industrialized Area. L. W. EWING, JR. *Corrosion*, **10**, No. 10, 315-317 (1954) October.

Details of protection from exterior corrosion of a large diameter products pipe line through heavily industrialized areas are given. Because of stray currents, limited space available for the installation and because the line had to be deeply buried it was considered advisable to coat and wrap the line very carefully and encase it in a concrete coating poured around the pipe in the ditch.

Coating and wrapping specifications and details concerning underwater crossing are given. 8064

5.6 Packaging

5.6.3, 6.2.2

A Simple Corrosion Test for Evaluating the Harmful Influence of Paper and Board on Iron. (In German). GERHARD SCHIKORR. *Das Papier*, **7**, No. 1/2, 18-19 (1953) January.

Paper clips were first degreased with an organic solvent, freed of their usual copper coating by treatment with an ammonia-hydrogen peroxide solution, then rinsed with distilled water and dried. They were then fastened to 10 by 4 cm paper or paperboard samples, stored in a desiccator at 90 percent RH and 18-19 degrees C and examined daily for one week for traces of rust.

Because the susceptibility of iron to rusting in the presence of paper is judged on the basis of the rust observed on the paper rather than on the iron, the accuracy of the test could be questioned. Preliminary experience has, however, indicated that accurate results are obtained with white, translucent paper. Colored papers have not yet been tested.

Note also: "Sweating" of Paper and Its Effect on Enclosed Iron Goods. (In German). Gerhard Schikorr. *Werkstoffe u. Korrosion*, **4**, No. 3, 81-86 (1953) March.

Describes series of tests for studying formation of "sweat" under varying conditions. Only paper which has been stored "dry" (i.e., at less than 65 percent relative humidity) should be used for packing iron. 8195

5.7 Treatment of Medium

5.7.1, 5.8.2, 4.6.1

Protective Coatings and Linings for Water Treating Equipment. JAMES BOYD SMITH. *Org. Finishing*, **15**, 13-15 (1954) Feb.

Coatings for degasifier units and filtration, coagulation and chemical feeding equipment. 14 references.—MR. 8278

5.8 Inhibitors and Passivators

5.8.2. 4.6.2

Reduce Corrosion in Your Return System. R. G. MONDOUX. *Modern Power & Eng.*, **48**, No. 9, 84-86, 154, 156 (1954) September.

Development of the use of volatile amines to inhibit corrosion in condensate lines. Advantages of volatile amines over film forming, ammonia, or alkaline materials are outlined. Morpholine type of amine volatilizes at extremely low concentrations in boiler water, and condenses at the same rate as the steam and in proper proportion to maintain protective pH values in all parts of the system. It is stable up to a boiler pressure of 2500 psi and to a temperature of 1200 degrees F in superheated steam. Illustrations show seriousness of corrosion problem in condensate systems and results obtained with use of volatile amines. 12 references.—INCO. 8173

5.8.2, 5.3.2

Behaviour of Galvanized Steel in Sodium Benzoate Solution. P. T. GILBERT AND S. E. HADDEN. *J. Applied Chem.* (London), **3**, No. 12, 545-548 (1953) Dec.

The corrosion-protection afforded by sodium benzoate to immersed steel is not extended to galvanized steel under similar conditions, exposed edges of the steel under the zinc coating being especially severely attacked. Electrochemical determinations indicated that possible changes in the surface condition of steel in contact with zinc while the former is the cathode may prevent the normal functioning of sodium benzoate when the steel becomes the anode. (Based on the Brit. Non-Ferrous Metals Res. Rept. No. R.R.A. 998 made available to members in July, 1953). 8203

5.8.2, 8.9.5

Barge Company Eliminates Corrosion with VPI. *Marine Eng.*, **59**, No. 8, 122, 124 (1954) August.

Annual savings in excess of $5,000 on maintenance for three double-hulled steel cargo barges are being realized by the Sargent Line Corp. of N. Y. as a result of their investigation of VPI as a means of preventing corrosion. The VPI crystals are used in a 12-inch space between the hulls.—INCO. 8176

5.8.2, 8.9.5, 4.4.6

A Promising Spray-Applied Inhibitor of Internal Corrosion of Oil Tank Ships. J. D. SUDBURY, D. A. SCHOCK AND F. W. MANN. *Corrosion*, **10**, No. 8, 253-258 (1954) August.

After reviewing briefly the characteristics, type of cargo and capacities of oil tank ships operating between Gulf and East Coast ports, the estimated cost of internal corrosion of the existing United States tanker fleet is estimated at $360,000,000 during the next 20 years. Causes of corrosion in tank compartments are scanned and current protective methods discussed.

Laboratory experiments using coupons are described in which soluble oil sodium dichromate, sodium nitrite, benzoic acid and a commercial organic inhibitor are tested. Because of the good showing made by a sodium alkyd aryl sulfonate, inhibitor formulations incorporating calcium sulfonate and sodium sulfonate with rosin amine stearate as a tackifying agent were tested. The best formulation was adopted for shipboard

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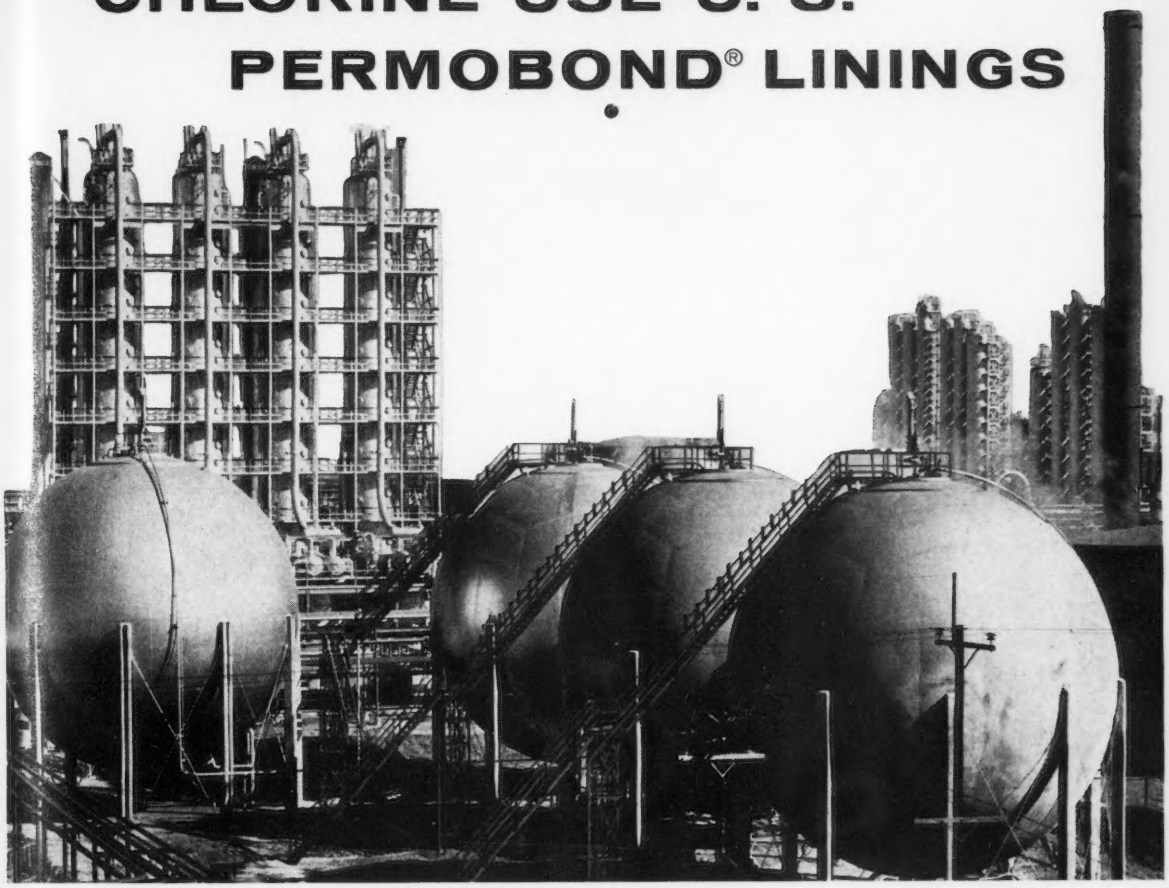

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tests which are now in progress. Efforts are being made to find hydrocarbons with lower flash points. 8259

5.8.3, 2.3.9

Radiometric Study of the Adsorption Characteristics of a Calcium Sulfonate Rust Inhibitor. VAN HONG, STANLEY L. EISLER, DAVID BOOTZIN AND ALEX HARRISON. *Corrosion*, **10**, No. 10, 343-348 (1954) October.

Calcium dinonyl naphthalene sulfonate was prepared using radiocalcium as the tagged atom. Tests similar to those previously reported for studying the adsorption of stearic acid were conducted. It was found that the amount of adsorption was slightly greater at 40 percent relative humidity than at 0 percent and then increased to a maximum at 100 percent relative humidity. This method of studying rust inhibitors should be applicable to other sulfonates as well as other types of rust inhibitors. 8235

5.8.3, 4.6.1, 5.8.2

Mechanism of Corrosion Inhibition by Sodium Metaphosphate Glass. JAMES C. LAMB, III AND ROLF ELIASSEN. *J. Am. Water Works Assoc.*, **46**, 445-460 (1954) May.

Effects of corrosion products in water; theory of film deposition. Diagrams, graphs, table. 19 references.—BTR. 8142

5.8.4

Properties of Films of Adsorbed Fluorinated Acids. E. F. HARE, E. G. SHAFRIN AND W. A. ZISMAN. Naval Research Lab., Washington, D. C. *J. Phys. Chem.* **58**, 236-239 (1954) March.

Monomolecular films of perfluorinated butyric, valeric, caproic, caprylic, capric, and lauric acids were prepared by physical adsorption on platinum from their solutions in organic solvents. Their wetting properties for a number of selected liquids were then characterized by contact angle measurements. Regular but small increments in the contact angles were observed with increasing acid chain length. Thus, although perfluorolauric acid monolayers provided the lowest energy surface yet reported, films of even the very short acids were significantly more nonwettable than other types of surfaces, including the fluorinated polymers studied earlier. For the shorter chain acids, monolayer formation was rapid. The two longest chain acids, however, required progressively longer periods of contact between the adsorbing surface and the acid solution for completion of a monolayer exhibiting maximum contact angle. The remarkable liquid repellency of the perfluoro acid monolayer exhibiting maximum contact angle. The remarkable liquid repellency of the perfluoroacid monolayers is caused by the presence of an exposed plane rich in perfluoromethyl groups. Electron diffraction examination of the longer chain acids reveals a molecular orientation consistent with this explanation. Included are surface-tension data for several new API hydrocarbons of exceptional purity.—NSA. 8227

5.8.4, 3.6.2, 4.6.1

Passivity of Metals. Part XII: Intense Attack at the Water-Line of Otherwise Passive Metal. A. M. PEERS AND ULICK R. EVANS. *J. Chem. Soc.*, **1953**, 1093-1102, April.

When iron is partly immersed in sodium chloride solutions containing phosphate, carbonate or a similar anodic inhibitor in small proportions, intense water-line attack occurs. As the phosphate or carbonate content increases, the area suffering corrosion is reduced; the attack becomes localized and usually intensified and finally ceases at high inhibitor concentrations. Water-line attack does not appear to be affected by special surface conditions, atmospheric impurities such as acid constituents, or slow evaporation. It is, however, greatly affected by the shape of the meniscus crevice and by the presence of films.

Results confirm the theory that the water-line attack is due to the slower replenishment of inhibitor in the crevices than on the remaining surface. It is thus a form of crevice corrosion, analogous to that produced at contact with a glass rod. Full details of experimental apparatus and technique are given. 8187

5.9 Surface Treatment

5.9.2, 8.4.3

Refinery Tests Show Less Metal Loss from Chemical Cleaning. N. H. PRATER. Magnolia Refining Co. *Oil Gas J.*, **53**, No. 6, 134-135 (1954) June 14.

Chemical cleaning of refinery equipment proved superior to sandblasting in tests on alloyed steel specimens (2.25% chromium, 1% molybdenum, 96.75% iron). Chemical cleaning solution contained 30% hydrochloric acid and various corrosion inhibitors. A table compares rates of metal loss by sandblasting and chemical cleaning.—INCO. 8286

5.9.3

Experiments on Sand-Blasting Media.

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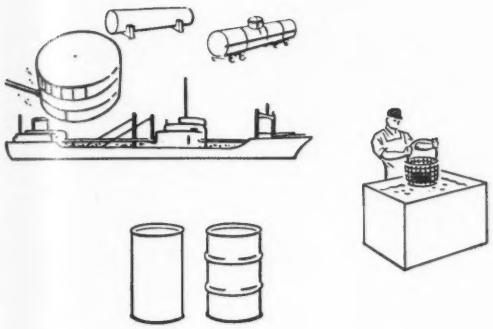

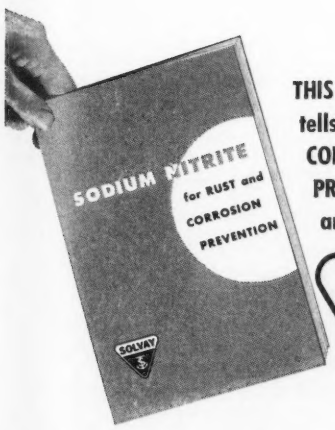

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W. GESELL. *Giesserei*, **41**, No. 7, 160-163 (1954) April 1. (In German).

Service life curves of granulated cast iron scrap and silica. Graphs.—MR. 8162

5.9.4

Anodic Behavior of Aluminum and Its Alloys in Sulfuric Acid Electrolytes. R. B. MASON AND P. E. FOWLE. *J. Electrochem. Soc.*, **101**, No. 2, 53-59 (1954) February.

An investigation of factors affecting the rate of dissolution of the anodic oxide films as they are formed. Production of thick, hard, abrasion-resistant coatings is favored by low temperature, high current density, and addition of oxalic acid to the bath.—BNF. 8166

5.9.4

Electropolishing with Rectified Current (in Part Based on Experiments by M. Ruiner and L. Hausleitner). (In German). J. STEINER. *Metalloberflache*, Sec. B, **6**, No. 5, B65-B69 (1954) May.

Investigation of the effect of rectified current of varying wave-form. Initial demonstrations in various cathode-ray oscillograms of wave-forms obtained with different circuits having regard to polarization and passivation. Polishing tests on copper and brass (phosphoric acid and a Jacquet bath), aluminum stainless steel (sulfuric acid-phosphoric acid-chromate) and aluminum in sulfuric acid anodizing bath. Slight ripple has no effect or a favorable one; more considerable ripple has a varying effect depending on conditions.—BNF. 8389

5.9.4

Where and When to Use Electropolishing. M. W. RILEY. *Materials & Methods*, **39**, No. 6, 104-106 (1954) June.

Short general article on the uses of electropolishing and its capabilities.—BNF. 8284

5.9.4, 6.3.15

Nitriding Improves Titanium Properties. Part II. J. L. WYATT AND N. J. GRANT. *Iron Age*, **173**, 124-127 (1954) Jan. 28.

Increased hardness, resistance to galling, improved creep rupture properties, and better oxidation resistance. Graphs, tables.—BTR. 8230

5.9.4, 6.4.2

Mechanical Properties of Aluminum Hard Coatings. H. A. JOHNSON. Wright Air Dev. Center. *Product Eng.*, **25**, No. 9, 136-140 (1954) Sept.

Types of finishes developed for aluminum are the oxide films produced by electro-chemical oxidation of the metal surface. Typical examples are Alcoa's Alumilite 225, 226, 725, and 726, and the Martin Hard Coatings. Hardness, wear resistance, corrosion and abrasion resistance of most of the aluminum alloys tested are increased to a significant degree. Tables give results of salt spray, atmospheric and humidity exposure tests on coated samples. Only failures that occured were in the 24S alloy. Graphs. —INCO. 8146

5.9.4, 6.4.4, 2.2.2

Anodically Surface Treated and Painted Cast Magnesium Alloy AZ63A-T6. FRED M. REINHART. U. S. National Bureau of Standards, Report No. 2533, June, 1953, 15 1.

A study was made of some variables, associated with surface treatment, on the adhesion of paint to anodically surface-coated cast magnesium alloy AZ63A-T6 (6.6% aluminum, 3.11% zinc, 0.2% manganese).

The first evidence of paint failure was observed after 184 months of exposure in the marine atmosphere of Norfolk, Va. On the basis of visual examinations there were no significant paint failures on any of the specimens. The adhesion of the different paint coatings to the anodically treated surfaces was excellent irrespective of cleaning pretreatments, sealing treatments or variations in time, temperature, pH, amperage and chemical composition of the treating solution ($Na_2Cr_2O_7$—$NaH_2PO_4.2H_2O$). No variable improved the adhesion of paint over that of the standard PT-13a anodic surface treatment method.—PDA. 8219

5.11 Design—Influence on Corrosion

5.11

Corrosion and Design—Discussion. Discussion before Soc. Chem. & Ind., Corrosion Group, London, May 4, 1954. *Chemistry & Industry*, No. 31, 957-958 (1954) July 31.

Protective treatment to be used must be considered at the design stage so that the structure is fabricated in such a way that the protective methods are carried out effectively. Metal (zinc and aluminum) spraying of structural parts prior to assembly, the use of welded assemblies to avoid corrosion—causing crevices and separation of dissimilar metals and materials are some subjects mentioned.—INCO. 8068

5.12 Metallurgical Treatment

5.12, 3.7.3

Freon-13 Operates in Cascade Systems at Minus 110°F. F. HERMANN. Tenney Eng., Inc. *Power*, **98**, No. 8, 120-121, 212 (1954) August.

Metal-treating techniques such as stress equalization, hardening, shrink-fitting and quick aging are being done now at controlled temperatures down to —120 degrees F. Soaking metals at these sub-zero levels can improve stability impact strength and toughness, or give increased hardness, longer life. In low-temperature test cells, researchers study effects of high altitudes or arctic conditions on aircraft parts, instruments and lubricants.—INCO. 8055

6. MATERIALS OF CONSTRUCTION

6.1 General

6.3.13, 6.3.9, 6.2.3

The High-Temperature, High-Pressure Oxidation of Metals: Progress Report. W. M. FASSELL, JR., AND R. C. PETERSON. U. S. Atomic Energy Commission Publ. (NP-4943), 1953, 8 pp. (on micro-cards).

The high-pressure, high-temperature oxidation characteristics of tantalum and molybdenum have been studied. In order to interpret correctly the oxidation data at various pressures, it is necessary to convert all pressures to oxygen concentrations. This correction has been applied to the oxidation of tantalum and it is shown that an activated adsorption of oxygen is involved in the pressure and temperature regions studied. A model has been developed which allows all the values obtained at temperatures <750C to be calculated with accuracy. The available information on molybdenum oxidation is reviewed. Experimental data indicate so far a very pronounced pressure effect and the law of oxidation at 600C is linear; no detectable amount of molybdenum trioxide was lost from the sample. The configuration of the oxidation curves was similar for tantalum and molybdenum and both show sensitivity to oxygen pressure.—MA. 8049

6.2 Ferrous Metals and Alloys

6.2.2, 3.2.3

Oxidation of Plain, Alloyed and Ductile Irons at 1300 Degrees F. J. A. CAMERON. *Corrosion*, **10**, No. 9, 295-298 (1954) Sept.

Oxidation tests of up to 4000 hours duration at 1300 degrees F were made on ordinary flake graphite gray irons, ductile iron and on highly alloyed cast iron having both flake and spheroidal graphite. It is concluded that ductile irons possess resistance to oxidation markedly better than that of flake graphite irons. In highly alloyed irons the difference is less pronounced at this temperature. Specimens exposed in atmospheric tempering furnace equipped with fan for circulation of air. 8115

6.2.2, 3.7.3

Production of Graphite Spherulites in Cast Iron by Treatment of the Metal with Argon. P. KONIG AND B. MARINCEK. *Schweiz. Archiv. angew. Wiss u. Tech.*, **20**, 41-44 (1954) February.

Describes combined zinc and argon treatments of irons and the forms of graphite so produced. Effects of carbon, sulfur and, in particular, manganese, exert predominant influence on results obtained. Table shows full compositions of irons treated. Full details of zinc treatment will be presented in forthcoming paper by authors in *Giesserei, Techn.-Wiss Beihefte*.—INCO. 8134

6.2.2, 4.7, 5.3.4

The Effect of Antimony Content of Iron-Saturated Molten Zinc on Its Attack on Iron. D. HORSTMANN. *Arch. Eisenhuttenw.* **25**, 207-213 (1954) May/June.

The dependence on time and temperature of the corrosion of iron by antimony-containing molten zinc was determined for antimony contents up to 5 percent. Zinc-antimony alloys were specially prepared from high-purity materials. The laws governing attack of iron by pure zinc apply in this instance also. At low and high temperatures, attack occurs in accordance with parabolic rate law of corrosion, and in the intermediate region attack proceeds linearly with time.—INCO. 8196

6.3 Non-Ferrous Metals and Alloys—Heavy

6.3.13

Where to Use Tantalum. TOM M. GAYLE. *Materials & Methods*, 39, No. 1 94-95 (1954) January.

Tantalum is resistant to practically all acids, particularly hydrochloric acid and aqua regia, but not to hydrofluoric, strong sulfuric and phosphoric acids. Below 300 degrees F it is practically immune to attack by dry or wet chlorine, bromine and iodine but not to fluorine or fluorinated compounds. Tantalum cannot be used in contact with

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117a

alkaline solutions, free sulfur trioxide or free hydrogen. It also corrodes badly in contact with other metals in an electrolyte.

Tantalum is malleable, ductile, weldable and resistant to erosion and thermal shock. Its thermal conductivity is about 3 times that of stainless steel and more than 40 times that of glass. Its mechanical strength is about that of steel. It has a high melting point and a low thermal expansion and it is not embrittled even when heated in vacuum. At high temperatures it tends to immobilize gases, thus maintaining a high vacuum. It forms unusually stable anodic surface films, thus offering high resistance to current flow in one direction (rectifying properties).

Applications in chemical engineering are given.—PDA. 8101

6.3.14, 3.2.2

On Tin Whiskers. F. C. FRANK. *Phil. Mag.*, **44,** No. 355, 854-860 (1953) Aug.

Author's view is that all that is needed to start the growth of whiskers on tin is an oxidizing or other reactive atmosphere, a small knob on the surface and a dislocation: oxidation of the whisker surface develops a stress which draws out a continuing thread of metal from the main mass.—BNF. 8376

6.3.15, 3.6.8

Eletrochemical Polarization of Titanium in Aqueous Solutions of Sodium Chloride. NORMAN . HACKERMAN AND COLBY D. HALL, JR. *J. Electrochem. Soc* **101,** 321-327 (1954) June.

Cathodic and anodic curves for titanium in neutral sodium chloride solutions over the range 0.02 microamp to 0.01 amp per sq cm. Graphs, tables. 8 references.—BTR. 8208

6.3.15, 3.7.3

Titanium—How to Deep Draw It. C. C. HIGGINS. Worcester Pressed Steel Co., *Tool Engr.*, **32,** No. 3, 75-76 (1954) March.

Commercially pure titanium can be drawn at room temperatures with fairly good results. All alloys of titanium harden so rapidly under cold working that stresses must be relieved after each draw to restore ductility necessary for subsequent forming operations. Biggest obstacle to successful drawing of titanium stems from the friction characteristics—its tendency to gall and seize. Some of this is overcome by use of proper die lubrication.—INCO. 8075

6.3.15, 5.9.4

Surface Hardening of Titanium by Carburising and Induction Heat Treatment. A. J. GRIEST and others. *Trans. Am. Soc. Metals,* **46,** 257-276 (1954).

Results of gas-, liquid- and pack-carburizing experiments on titanium and titanium alloys. Wear resistance was improved.—BNF. 8110

6.3.15

Titanium. Pt. 1—Now You Can Use Titanium. Pt. 2—How to Grind Titanium. Pt. 3—How to Hot Work Titanium. Pt. 4—How to Heat Treat Titanium. Pt. 5—How to Form Titanium. C. I. BRADFORD. Rem-Cru Titanium Inc. *Steel;* **134;** Nos. 19, 20, 21, 22 & 23; 148-150, 118-119, 100-101, 92-93, 136-137 (1954) May 10, May 17, May 24, May 31, June 7.

Pt. 1 discusses properties and availability. Pt. 2 discusses grinding and gives a list of coolants that have given good results. Speeds are usually below those for other metals. Pt. 3 discusses furnaces and atmospheres, heating equipment, temperatures, heating time, cooling rates, annealing, stress relief, surface conditioning and shrinkage. Pt. 4 discusses heat treating, surface hardening, stress relieving, annealing and metallography. Pt. 5 discusses bending, brake and stretch forming, hydropress, drop hammers, punch press, spinning and dimpling. Illustrations.—INCO. 7991

6.3.15, 1.4

Titanium Metallurgy. HUGH E. VOREss, Compiler. U. S. Atomic Energy Commission, TID-3039, April 14, 1953, 57 pp.

A bibliography of unclassified report literature containing 366 references. Includes author, subject, and numerical indexes.—BTR. 7976

6.3.15, 2.2.2, 2.2.7, 3.6.6

Corrosion Properties of Titanium in Marine Environments. H. B. BOMBERGER, P. J. CAMBOURELIS AND G. E. HUTCHINSON. Rem-Cru Titanium Inc., Paper before Electrochem. Soc., Wrightsville Beach, Sept. 13-16, 1953. *J. Electrochem. Soc.,* **101,** No. 9, 442-447 (1954) Sept.

Data are presented on the behavior of commercially pure titanium and several common structural metals, including Monel, Inconel, 320, 316 and 347 stainless steels, exposed up to 5 years at Kure Beach. Tests include exposures to atmosphere, quiet and flowing sea water, jet impingement, stress corrosion and galvanic couples. Tests indicate that titanium is unaffected by marine environments. Titanium coupled to Inconel, silver and 316 and 302 stainless steels had little effect on corrosion rates of these materials, but rates of Monel, copper, low-carbon steel and aluminum alloys were increased considerably. Photographs of specimens, tables, 12 references.—INCO. 8045

6.3.15, 3.8.4

The Logarithmic Growth Law for the Oxidation of Titanium. J. T. WABER, G. E. STURDY AND E. N. WISE. *J. Am. Chem. Soc.,* **75,** No. 9, 2269-2270 (1953) May 6.

A note. Re-investigation of the oxidation of titanium below 350 C confirms the work of Alexander and Pidgeon. [*Can. J. Research,* (B), **28,** 60 (1949)], the oxidation following the logarithmic growth law. The break in the Arrhenius plot reported by Gulbransen and Andrew. [*Trans. Am. Inst. Min. Met. Engrs.,* **185,** 741 (1949)] is due to the change from the logarithmic to the parabolic rate law at temperatures increasing above 350 C.—MA. 7980

6.3.15, 5.9.1

Comments on the Finishing of Titanium. J. STARR. *Products Finishing,* **17,** No. 6, 38-42 (1953).

Titanium may be descaled in caustic melts at 800F and brightened in 2% hydrofluoric acid-10% nitric acid (vol.). The metal is anodized for low temperature applications in chromic or sulfuric acid, followed by dyeing or organic finishing. Little success has yet been achieved in electroplating titanium through evaporated coating of aluminum, gold or tungsten have been successfully applied, as have ceramic coatings on some titanium alloys.—EL. 7887

6.3.16

Flow and Fracture Characteristics of Annealed Tungsten. J. H. BECHTOLD AND P. G. SHEWMON. *Trans. Am. Soc. Metals,* **46,** 397-408 (1954).

Tensile tests on annealed specimens ground from swaged rod. The tests were made over the temperature range —196 to +900C. The transition from brittle to ductile behavior took place at about 150-450C.—BNF. 7998

6.3.19, 3.7.2

Intercrystalline Corrosion of Zinc-Aluminium-Copper Alloys. (In German). E. PELZEL. *Metall* (Germany), **8,** No. 5/6, 169-173 (1954) March.

Intercrystalline corrosion is liable to occur in zinc-aluminum alloys particularly when the percentage of impurities e.g. lead, cadmium, tin, bismuth and thallium, exceeds certain small limits. The corrosion process was studied in zinc-aluminum alloys, (some rich, some phere at 95 degrees ±1.5 degrees C. to 0.7 percent of lead, in a moist atmospoor in aluminum), some containing up The zinc-aluminum alloys containing from 0.1-0.8 percent aluminum and composed of zinc of purity 99.975 percent showed intercrystalline corrosion after ten days exposure. Homogenization of the alloys delayed the corrosion, which was liable to occur more especially at regions of contact between the nobler impurities and the alloy β-phase. Increasing the copper content in zinc-aluminum alloys containing 0.8 percent of aluminum tended to check intercrystalline corrosion. An alloy containing 0.3 percent aluminum and 1.6 percent copper was found to be absolutely resistant to intercrystalline corrosion after three days exposure to vapor. Addition of magnesium improved the corrosion resistance. Tests were also carried out on zinc-aluminum alloys containing 25-50 percent aluminum.—ZDA. 8337

6.3.19

The Wrought Zinc Alloy Zn-All-Fe. J. SCHRAMM. *Metall,* **7,** No. ¾, 93-102 (1953).

A report on the properties, production and working of this alloy, which was developed during the war years as a substitute for the alloy ZnCu4Pb, when copper was in short supply. ZnAllFe has the specification: aluminum 1.0-1.4, iron 0.3-0.6, copper 0.1-0.3, manganese 0.15-0.35, magnesium 0.005-0.015%, balance zinc—as 99.975% or 99.99% metal; iron,, manganese and copper are added as zinc-base hardener alloys and up to 30% process scrap may be used. Detailed accounts are given of the make-up, melting, casting, structure, extrusion, drawing, forging, machining and corrosion-resistance (to humid atmospheres) of the alloy and, in many cases, in comparison with similar details for the alloys ZnCu4Pb, ZnCu2Pb and Mg-free ZnAllFe; these may be summarized briefly as follows: 1) Melting—in gas-fired crucible furnaces or L.F. induction furnaces, with a cover of NaCl+KCl. 2) Casting—at 750C by the intermittent Tutenguss, or semi-continuous Wasserguss processes, the former being preferable, as it gives very sound ingots having a bright smooth surface with no sweat beads. 3) Structure—fine-grained, and consisting of a ground mass of Zn solid solution in which are embedded very hard crystals of binary or ternary compounds of aluminum, iron and manganese. 4) Extrusion—at 220-310C with container temperature 10-40C lower, at speeds of 0.8-1.0 m./min. and reduction of ⩾ 95%. 5) Drawing—up to 90% reduction without intermediate anneals at temperature of ⩽ 20C (to avoid cold shuts) and ⩾ 50C. 6) Forging—at 220-280C. 7) Mechanical Properties—ex-

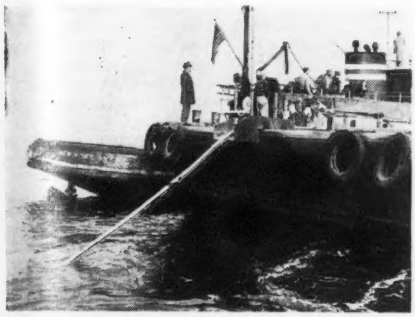
16

TONS OF LEAD PER MILE

Three lead-sheathed submarine cables, each 3 miles long were recently laid side-by-side across the Hudson River, forming a main artery for A.T. & T.'s new switching center at White Plains, N.Y. They are the longest and the largest containing coaxial conductors ever made for underwater use. Over 300,000 lbs. of lead were used in manufacturing the 9 miles of king-size cable which is 4⅜" thick and weighs 26½ lbs. per ft.

Extruded lead tubing has been used as protective sheathing on electric cable for either voice or power transmission since the late 1800's. The choice of lead for this application is dictated chiefly by a number of highly desirable characteristics inherent in the metal; its pliability facilitates the reeling and unreeling of the cable; its low melting point permits the sheathing to be extruded over the core without damage to the insulation, and it is the only commonly available metal which successfully withstands all of the corrosive influences encountered in the service-life of cable—whether in the air, underground or beneath the sea. This is of particular importance in submarine cables where repair work can be a tremendous undertaking.

Other factors in favor of lead sheathing is that it is malleable, and that convenient lengths of the cable are easily joined with the help of two other lead products, lead sleeves and solder. Finally, when the life of the cable is spent, the lead is easily reclaimed and can be returned to the market for another cycle of service.



above: Cable being lowered into water from stern of barge. One tug supplied movement while others kept barges along buoy line marking trench scooped out of river bottom.

right: Warped into the cable dock at Western Electric's Point Breeze Works are the loaded barges ready to carry the big submarine cable to the site of its installation.

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truded rod: U.T.S. 27 ± 3 kg./mm.², elongation 10-30%, Brinell hardness 80-100 kg./mm.², impact and notch-impact strengths of 9-14, and 0·6-0·9 m.-kg./cm.². 8) Ageing—seven days at 95C raises the U.T.S. to ~ 36 kg./mm.²; higher temperatures can be used with shorter times; recrystallization takes place at 250C. 8 references.—MA. 7908

6.3.20, 3.2.3, 4.3.5

The Reaction of Nitrogen with, and the Diffusion of Nitrogen in, Beta Zirconium. M. W. MALLETT, J. BELLE AND B. B. CLELAND. *J. Electrochem. Soc.*, **101**, No. 1, 1-5 (1954) Jan.

Determination of rates at 975-1640 degrees C at 1 atm. pressure; a parabolic law was observed for the rate of reaction. Thermodynamic properties have been calculated from the result. Materials used were double arc-melted and cold-rolled iodide zirconium, and nitrogen purified by passage over heated zirconium.—BNF. 8180

6.3.20, 5.9.4, 3.2.3

The Influence of Anodic Oxide Films on the Thermal Oxidation of Zirconium. J. J. POLLING AND A. CHARLESBY. *Acta Metallurgica*, **2**, No. 5, 667-674 (1954) Sept.

Changes in the thermal oxidation of zirconium due to an initial electrolytically-formed oxide layer are studied. Increase in thickness of the oxide on heating is measured optically and gravimetrically. Effect of the initial layer is the same as if it has been produced thermally, i.e., there is no difference in the oxidation behavior of two specimens covered with initial oxide films of the same thickness, one of which has been grown electrolytically and the other thermally. Growth of the oxide layer is approximately logarithmic up to temperatures of 260 degrees C, cubic at 300 degrees C and at higher temperatures it tends towards a quadratic function of time. For thick films there is a linear law probably due to cracking of the oxide. These rates of growth are in agreement with theoretical calculations based on the oxidation theory of Mott. 13 references.—INCO. 8283

6.4 Non-Ferrous Metals and Alloys—Light

6.4.1, 3.7.3

Resistance Welding of Light Metals. CHARLES GUINARD. *Rev. aluminium;* Nos. 195 and 196; 35-40, 67-70 (1953).

Guinard discusses the characteristics of the direct single and 3-phase, and stored-energy (inductance and storage condenser) types of resistance-welding machines. The choice of machine is considered, and then factors influencing electrode pressure and optimum spot size for spot welding various sheet thicknesses are enumerated. This is followed by an indication of the correct interpretation and correction of defects shown in trial runs on test strips, after which design factors influencing weld quality are outlined as well as subsequent treatments for the protection of welds against corrosion. The concluding sections deal with the application of the earlier principles to seam and flash-butt welding.—MA. 7705

6.4.2, 1.6, 3.7.3

Welding Alcoa Aluminum. 176 pp., 5¼ x 8¼ inches, 1954. Aluminum Company of America, 1501 Alcoa Bldg., Pittsburgh. Gratis.

This successor to the Alcoa booklet "Welding and Brazing Alcoa Aluminum" brings up to date the information on aluminum welding. Brazing will be covered in a booklet to be issued later. The booklet covers theory and technique in inert gas tungsten welding, inert gas consumable electrode welding, spot and seam welding, flash welding; metal arc, carbon arc, atomic hydrogen welding; gas welding; welding aluminum castings, pressure welding, performance, quality control, and safety. Numerous tables of data on mechanical properties are given and illustrations are included, of types of welds. A topical index is included. 7542

6.4.2

New Commercial Aluminum Alloy, K155 Announced. *Light Metal Age*, **11**, No. 5/6, 22 (1953) June; *Machine Design*, **25**, No. 7, 196 (1953) July.

K155 (nominal 0.9% magnesium content), a new magnesium-type aluminum sheet alloy for general metalworking requirements announced by Kaiser Aluminum & Chemical Sales, Inc., has the same general mechanical property limits, availability, price and tolerances as alloy 3S (manganese-type alloy). It forms easily, has good corrosion resistance, and is suited for taking anodized finishes. It is available in plate, flat sheet, coil and circle form in all tempers in the H1 and H3 groups. Illustration.—INCO. 7108

6.4.2

Efficient Structure in Aluminium. M. BRIDGEWATER. *Metal Ind.* (London), **83**, No. 6, 105-108 (1953).

Bridgewater discusses the problems that arise in considering aluminum as a structural material; they are different in many respects from those of steel. The alloy selected for review is the aluminum-magnesium-silicon alloy, which, although not the strongest, is far superior to the high-strength alloys in corrosion-resistance and more economic.—MA. 7384

6.4.2

Some Creep Characteristics of a Group of Precipitation-Hardening Alloys Based on the Alpha-Copper-Aluminium Phase. J. P. DENNISON. *J. Inst. Metals* (London), **82**, No. 3, 117-128 (1953) November.

The creep and creep-rupture characteristics of precipitation-hardening alloys based on the α-copper-aluminum phase and containing cobalt, chromium, iron, nickel, titanium or zirconium have been examined.—BNF. 8354

6.4.2

Factors Influencing Brittleness in Aluminum-Magnesium-Silicon Alloys. I. R. HARRIS AND P. C. VARLEY. *J. Inst. Metals*, **82**, No. 8, 379-393 (1954) April.

Effects of composition, heat-treatment, cold-work and structure on the brittleness and mechanical properties of wrought aluminum-magnesium-silicon alloys containing 0-2 percent silicon and 0-2 percent magnesium have been investigated. Beneficial effects of additions of manganese or chromium (for maximum strength with good ductility, combined additions of either plus copper).—BNF. 8060

6.4.2

Properties and Applications of Sintered Aluminum (S.A.P.). (In French and German). R. IRMANN. *Aluminium Suisse*, **4**, No. 1, 24-32 (1954) Jan.

Preparation and properties of the powder; fabrication and mechanical properties of SAP; resistance to creep and fatigue; physical properties; applications.—BNF. 8150

6.4.2

Aluminum Coverings for Thermal Insulation. HARRY W. FRITTS. *Corrosion* (News Section), **10**, No. 6, 1 (1954) June.

Aluminum alloys have a number of special advantages as a covering for thermal insulation: light weight, excellent weather properties, corrosion resistance, good radiant heat reflection. However, certain limitations have to be taken into account. In the presence of moisture many common insulating materials either have an alkaline leach or will support electrochemical corrosion because of the development of concentration cells. Either or both of these conditions can cause corrosion of aluminum alloys. Where moisture is anticipated a barrier must be incorporated which will prevent contact between aluminum and the moist insulation. Aluminum-alloy sheathed insulation in packaged units is available for covering pipe. Experience has shown that aluminum sheet is superior to other common coverings in sea coast and industrial atmospheres, even those contaminated with many types of chemical fumes and dusts.—ALL. 8183

6.4.2

Effect of Very Small Impurity Contents on the Electrical Conductivity at Very Low Temperatures of Super-Pure Aluminium. (In French). M. CARON, P. ALBERT AND G. CHAUDRON. *Compt. Rend.* **238**, No. 6, 686-688 (1954) Feb. 8.

Conductivity measurements at liquid helium temperatures enable 99.998, 99.996, 99.99, 99.98 and 99.95 aluminum to be clearly distinguished.—BNF. 8052

6.4.2, 1.2.2

Aluminium World Survey. Brochure. April, 1954, 128 pp. Issued by the Metal Bulletin, Birkett House, 27 Albemarle Street, W. 1.

In a series of 20 articles the aluminum industry at home, in Canada and Europe is covered as well as the position in various technical fields, including fabrication, building, aircraft, secondary aluminum, holloware, pressure cookers, foil, chemical industry and anodizing.—BNF. 8186

6.4.2, 3.4.4, 3.4.7

Irreversible Potentials and Corrosion Behavior of Aluminum in Buffered Solutions. (In Russian). A. YA. SHATALOV AND YU. A. MIKHAILOVSKII. *Zhur. Fiz. Khim.*, **27**, 1025-1031 (1953) July.

The electrode potential of aluminum in buffered solutions of chloride ions with a pH range from 2 to 12 was investigated. The irreversible potential of aluminum is changed by the pH, with the curve first falling with rise in pH and then rising sharply at pH 8. The potential is graphed against the current density for a constant pH and constant Cl^- concentration. Corrosion curves are given.—NSA. 8198

6.4.2, 3.6.6

Aqueous Static Corrosion of Aluminum Alloys Coupled to Stainless Steel and Zirconium at 350°F. P. O. STROM, M. H. BOYER AND I. M. LITZ. Livermore Research Lab., Calif. Research

and Development Co., Contract AT(11-1)-74, Jan., 1954, 14 pp.

The corrosion of several commercial aluminum alloys, electrically coupled to type 302 stainless steel and to zirconium, was studied at 350 degrees F in pure water. Those aluminum alloys coupled to steel showed appreciably higher initial rates of attack than those coupled to zirconium. Roughly equal rates were observed once the protective film of corrosion product had formed. Long-term corrosion rates were about the same as for uncoupled aluminum alloys, about 0.35 mil/yr at this temperature.—NSA. 8395

7. EQUIPMENT

7.1 Engines, Bearings and Turbines

7.1, 4.3.3

The Problem of Fuel-Oil Ash Deposition in Open-Cycle Gas Turbines. A. T. BOWDEN, [illegible] DRAPER AND H. ROWLING. *Proc. Inst. Mech. Engrs.* (London), (A), 167, No. 3, 291-312 (1953).

Nature of ash-forming constituents, chemistry of the ash and mechanism of deposition, ash removal, reduction of deposition by combustion control or use of additives (silicon dioxide, zinc oxide, magnesium oxide, etc.). Troubles due to vanadium compounds are stressed.—BNF. 7388

7.1, 3.2.2

Prevention of Babbitt Blisters in Thrust-Bearing Pads. R. A. BAUDRY, D. W. GUNTHER AND B. B. WINER. Westinghouse Elec. Corp. Paper before ASME, Semi-Ann. Mtg., Los Angeles, June 28-July 2, 1953. *Trans. Am. Soc. Mech. Engrs.*, 76, No. 2, 255-260 (1954) Feb.

It was established that hydrogen contained in commercial steels is responsible for the Babbitt blisters observed in bearings. A low level of hydrogen content is required to prevent the formation of blisters. This low level is obtained and insured by suitable heat-treatment and quality control. Incorporation of processes to remove hydrogen into the manufacture of thrust-bearing pads has resulted in the complete elimination of Babbitt blistering. Graphs and 15 illustrations.—INCO. 7117

7.3 Pumps, Compressors, Propellers and Impellers

7.3, 3.5.3, 2.3.7, 6.3.6

The Cavitation-Erosion of Ships' Propellers. J. BALHAN. Pub. #104 of Netherlands Marine Eng. Res. Sta., Wageningen. *Ingenieur;* 65, Nos. 6 & 7; W29-W40; W41-W45. W52. (1953) Feb. 6, Feb. 13. *Engrs'. Digest* (Abridged translation), 14, No. 5, 163-167, 170 (1953) May.

Conditions for cavitation, 3 types of cavitation, laminar, burbling and cloud, theoretical considerations on cavitation-erosion, testing of propellers in the cavitation tunnel of Marine Eng. Res. Sta., and rapid cavitation-erosion tests by the magnetostrictive method are covered. Various bronze materials, some of which were covered with synthetic resins, plastic or rubber coatings, were tested. Lowest losses in weight were obtained with aluminum bronzes, consisting of 81.5% copper, 10.13% aluminum, 3.72% nickel, 4.55% iron, and 0.10% lead. The various coatings have good results. Diagrams.—INCO. 6235

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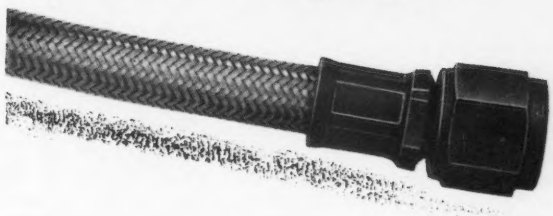

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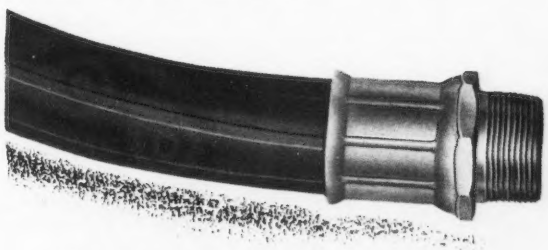

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7.4 Heat Exchangers

7.4.1, 8.4.2

Combating Heat-Exchanger Corrosion in Glycol-Amine Gas-Treating Plants. P. PARADES AND J. W. CRONENBERG. El Paso Natural Gas Co. Paper before N.G.A.A. Ann. Mtg., Dallas, April 21-23, 1954. *Oil Gas J.*, **53,** No. 7, 159-161 (1954) June 21.

Tests and observations showed that aluminum, chromium-molybdenum, stainless steel 18-8 and Type 304), Monel and Iconel were suitable as heat-exchanger materials. Croloy 5 and aluminum alloys, 3S and 3S Alclad, were used for economical reasons. El Paso increased heat-exchanger life from 3¾ months to 2 years by using aluminum. Preliminary tests with 61S-T6 aluminum and anodized aluminum are promising. Flow-diagram of glycol-amine process is given. 7 references.—INCO. 8309

7.4.2, 4.6.4

Longer Service from Heat Exchangers. J. D. MUNRO. Stand. Oil Dev. Co. Paper before Am. Petroleum Inst., Mid-year Mtg., Houston, May 10, 1954. Preprint A.P.I., May, 1954, 57 pp.; *Oil Gas J.*, **53,** No. 12, 226, 228, 231-232, 234, 236, 238-240, 242-244, 246, 249-250 (1954) July 26.

Severe corrosion and other forms of deterioration in shell and tube exchangers handling cooling water were experienced by Standard Oil Co. N.J.). Majority of exchanger problems were attributed to erosion-corrosion attack of tube ends and tube sheets caused chiefly by velocity and turbulence of the water. Other types of attack included galvanic action, graphitization, impingement, dezincification, deposit attack and stress corrosion. Experimental and development work on methods of corrosion prevention, such as chemical injection, construction materials, protective linings, and cathodic protection, were extensive. Monel, 70:30 copper-nickel, aluminum and stainless steel tubes give satisfactory service in salt-water exchangers, but their higher cost or other factors limit their use. Tables and 8 references.—INCO. 8161

7.4.2, 4.2.3, 2.2.3, 2.3.2, 1.6

Corrosion and Deposits in Regenerative Air PreHeaters. J. F. BARKLEY, HILMER KARLSSON, A. A. BERK, C. F. STARK AND L. R. BURDICK. U. S. Bureau of of Mines. Report of Investigations 4996, 1953, August, 73 pp.

Field tests on the composition and buildup of deposits and on the rate of corrosion of 66 different materials were made under regular operating conditions of an air preheater serving an underfeed stoker-fired water-tube boiler. The plant equipment is described, and pertinent plant operating data over the 5½-year period of the tests are tabulated. The average rates of corrosion under different conditions of attack by sulfuric acid are given for the various materials. Cor-Ten, a low-alloy plate steel, is used as a reference material.

Predominant characteristics of all the deposits were partial solubility in water, presence of sulfates and acidity. The solubilities ranged from 13 to 98%, the soluble part being mostly sulfates. The acidities of 1% coldwater extracts ranged from pH 1.8 to 3.4, depending upon the action of the soluble sulfates.

Both physical and chemical actions are involved in deposit buildup. Physical actions include the trapping of particles in the flue gas by the plate surface and the scouring action, particularly of the larger particles. Chemical actions involve formation of sulfate from acid reaction on dust, on the deposit and also on the plate if it is not acid-resistant. These reactions proceed to some extent at temperatures well above the dew point of the gases and effects are significant because of the large quantities of gas and the relatively long periods of time involved. The corrosion of a test plate was due mostly to sulfuric acid action.

Corrosion can be prevented by using materials that are not attacked by sulfuric acid. Corrosion and deposits can be lessened by reducing the sulfur in the fuel; by preventing formation of sulfur trioxide in flue gases; by additions of calcium hydroxide, calcium carbonate, or magnesium carbonate, to the fuel, the flue gases, or the air; by removal of deposits from air preheaters during operation and dust in the flue gases before they enter the air-preheater and by reduction of moisture in air and fuel.

Progress in air-preheater design demands that the temperature of the exit flue gases be lowered below those now attained.

Fairly satisfactory accelerated laboratory corrosion tests are given.—PDA. 8356

7.5 Containers

7.5.5, 4.6.6

Steel Tanks as Distribution Reservoirs. C. K. WELLS. Long Beach Water Dept. *J. Am. Water Works Assoc.*, **45,** 569 (1953); *Water & Sewage Works*, Pt. 2, **101,** No. 5, R33-R34 (1954) May.

Interior steel surfaces of tank reservoirs are protected against corrosion by cathodic protection of submerged surfaces and coatings above the average water line. An oil-saturated base prevents soil corrosion. Use of reinforced and prestressed concretes are considered.—INCO. 7878

7.5.5, 5.2.2

Improvement in Tank Bottom Protection. HANS SCHMOLDT. *Petroleum Engr.* **25,** No. 5, D29-D30, D32, D34 (1953) May.

A new application of cathodic protection by Cities Service Pipe Line Co. is designed to arrest attack of salt-water corrosion on the internal bottoms of seven new 134-ft. diameter, floating roof crude-oil storage tanks having a 120,000-bbl. capacity.

Ninety-seven magnesium anodes totaling 2522 lb., designed for a 12-year life are being installed in concentric circles on each tank bottom. The 26-lb. cast anodes are in the shape of flat disks, 2¼ inches thick and 15 inches in diameter, which permits their installation close to the tank bottom and asures their functioning even in a minimum depth of low-resistance salt water. A 6 by 1 inch pipe nipple quartered and spread four ways is the core of the anode; the threaded end of the nipple protrudes into a 3-inch diameter, 1-inch deep recess in the bottom of the anode. Half of a 1-inch pipe coupling is welded to the tank bottom, allowing simple installation and quick replacement by new anodes. The ineffective consumption of magnesium by local anode action is controlled by installing each anode in the middle of a hot-applied coal-tar enamel insulating pad, ¼-inch thick, 48 inches in diameter and by coating the top and bottom of the anode with a similar composition to reduce the surface area exposed to the salt water.—PDA. 7903

7.5.5, 7.5.2, 6.4.2

Big Aluminium Containers in Switzerland. E. J. ZIMMERLI. *Modern Metals*, 9, No. 8, 33-36 (1953) September.

In Switzerland breweries, food-stuff industries and chemical industries have adopted aluminum containers to a very large extent. Two types of material are mainly used for containers: pure aluminum of 99.3 to 99.69% purity and type Al-3Mg containing 2 to 3% magnesium and 0 to 0.4% manganese. Heat-treated containers can have maximum contents of only 500 to 1000 liters (528 to 1056 quarts), larger containers have to be fabricated from the non-heat treated types. Recently the argon-arc process has been generally adopted for construction. Corrosion protection is attained by anodizing, which is used not only for containers such as milk churns and beer barrels but also for large tanks and reservoirs in the dairy industry. Aluminum containers have been protected by synthetic resin lacquers against the more aggressive chemicals. Typical Swiss containers are: 7000-gallon capacity beer-storage tanks lined with plastic coating, beer fermenting chambers, 90,000 to 150,000-gallon tanks for the storage of organic oils containing acids, square aluminum tanks for storing fatty acids and a number of aluminum movable containers. Switzerland has also developed special container cars.—ALL. 7879

7.6 Unit Process Equipment

7.6.4

Faulty Firing as a Cause of Boiler Corrosion. (In German). K. SCHWARZ. *Brennstoff-Warme-Kraft*, **5,** 94-96 (1953) March.

Describes results of combined action of flue gas depositions and combustion. —BTR. 7896

7.6.6, 8.5.3

Appraisal of Alkaline Digester Corrosion Problems. H. O. TEEPLE (Inco.). *Southern Pulp Paper Mfr.*, **16,** No. 8, 62-64, 66 (1953) Aug.

Paper presented before the joint fall meeting of the Southeastern and Southern Divisions of the American Pulp and Paper Mill Superintendents Assoc., October 8-10, 1952, at Roanoke, Virginia.

Discusses present-day deficiencies of carbon-steel digesters for alkali pulping and steps to remedy them. Inconel and Type 316 stainless steel are satisfactory. Type 410 stainless steel has insufficient corrosion resistance; 18/8 steels do not resist localized corrosion in the vapor space. 8024

7.7 Electrical-Telephone and Radio

7.7, 6.4.2

Aluminium in (Electrical) Switch and Distribution Installations. (In German and French). G. DASSETTO. *Aluminium Suisse*, **4,** No. 2, 38-55 (1954) March.

A detailed, thorough discussion of 99.5 percent aluminum and Anticorodal with some comparisons with copper; tables showing electrical, physical and mechanical properties; available forms; maxi-

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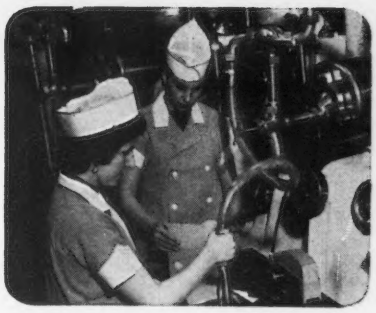

AS TUBING OR HOSE to pipe taste-sensitive liquid foods or corrosive chemicals. Tygon Tubing is glass-clear, flexible as a piece of string, resistant to acids and alkalies, non-toxic, sterilizable, and is made in bores from 1/16″ to 2″.

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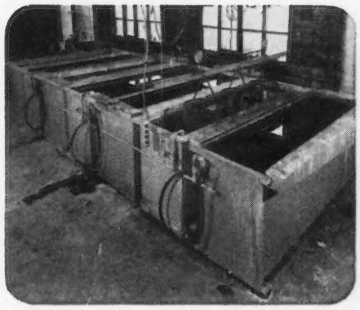
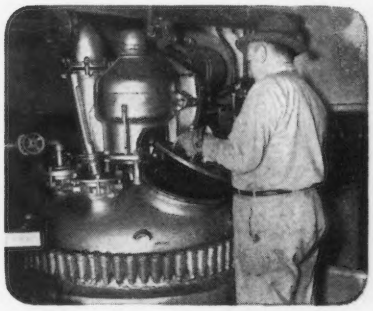
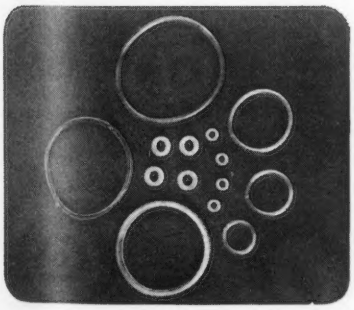


AS A HEAVY-DUTY LINING to protect the interior of pickling, plating, chemical processing and storage tanks from destruction by corrosive solutions. Easier to install than rubber linings, Tygon can be applied to tanks of any size or shape.



AS A CORROSION-RESISTANT GASKETING. Tygon shows no chemical deterioration with age. Gaskets remain flexible and tight, unaffected by weather or exposure to chemicals. Tygon gaskets are available in an almost unlimited size range.



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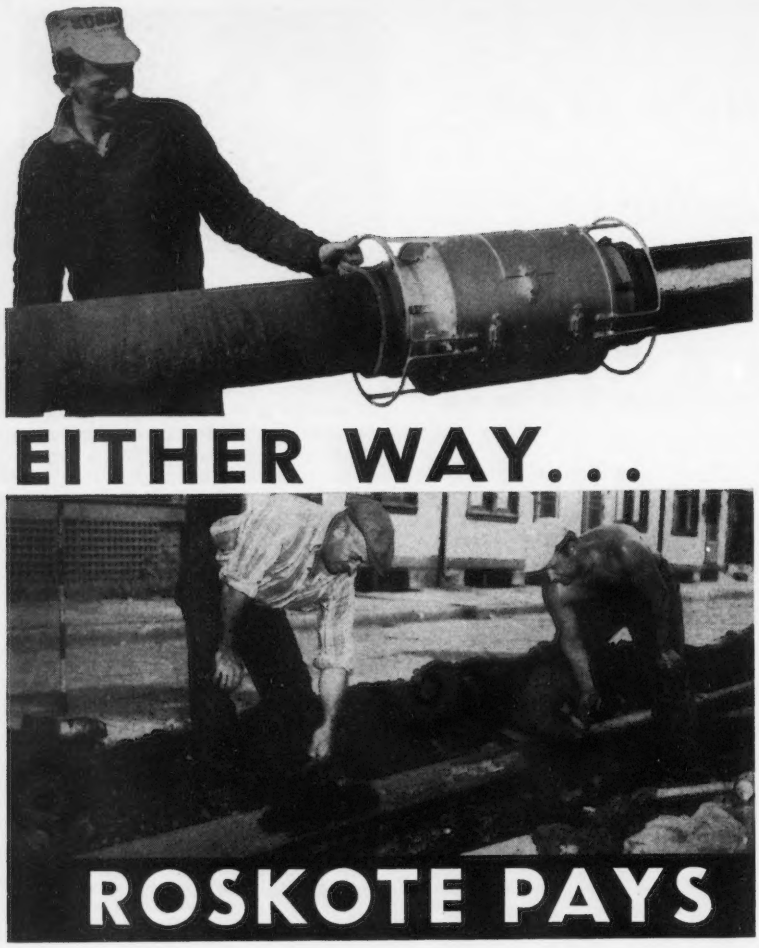

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mum current loads and effect of conductor temperature, cross-section, arrangement, and air movement; effect of short-circuits and arcing; mechanical strength; resistance to atmosphere and chemicals; fabrication; joints and connections (welding, screwing, etc.) for aluminum and aluminum-copper; economics.—BNF. 8054

8. INDUSTRIES

8.8 Group 8

8.8.1, 6.2.5

Special Steels for the Petroleum Chemicals Industry. E. SMITH. Paper before Soc. Chem. Ind. & Inst. of Petroleum, London, March 2, 1953, preprint, 11 pp. *Chemistry & Industry,* Suppl., **1953,** S9-S17, August 10.

Many corrosion- and heat-resisting steels which are available to the petroleum chemicals industry are discussed with their different characteristics, the reason for these characteristics and their influence on the applications of the individual steels in the industry. The austenitic type of stainless steel is used for plant construction to resist chemical attack. The 18-8 composition gives the required resistance and by the addition of 3% molybdenum, an even higher degree of corrosion-resistance is achieved. Properties of various corrosion-resisting steels are listed and the effect of various acids, nitric, sulfuric, hydrochloric, phosphoric and acetic on these steels is shown in table form as well as the properties of heat-resisting steels.—INCO. 7899

8.9 Group 9

8.9.3, 5.4.5, 5.2.1, 1.2.2, 2.3.5

Corrosion for Pipeliners. I. Introduction to Corrosion. II. Pipeline Coatings. III. Cathodic Protection. IV. Testing. V. Cathodic Protection Equipment. VI. Corrosion Control an Economic Necessity. STARR THAYER. *Pipe Line News;* **25;** 21-22; 44-47; 31-32+; 34-37; 40+; 39-41; (1953) March, April, May, June, July, Aug.

Part I. Describes causes of corrosion in steel and general methods of testing.

Part II. Describes use of cold paints, coal tar and asphalt base enamels. Considers special applications and future prospects.

Part III. Practical application of cathodic protection, sacrificial anodes, rectifiers, preliminary tests, ground beds and interference.

Part IV. Describes method of measuring the potential difference between the protected metal and surrounding soil.

Part V. Describes use in production equipment and tools available to the corrosion engineer.

Part VI. Discusses costs of corrosion to the pipeline industry. 7973

8.9.3, 5.4.7

Streamlined Internal Cleaning-Coating Operation. F. L. RESEN. *Oil Gas J.* **53,** No. 8, 112-113 (1954) June 28.

Newly developed unit is designed to clean the internal surface of pipe joints on one pass and spray it with a corrosion-resistant protective coating on the reverse pass. The protective coating is based upon Epon resin (from condensation polymers of epichlorohydrin and bisphenol). Developed by Crutcher-Rolfs-Cummings, Inc. Illustrations.—INCO. 8020

Index to Advertisers

Vol. 11 June, 1955 No. 6

	Page
Alco Products, Inc.	104
Amercoat Corporation	Inside Front Cover
American Chemical Paint Co.	112
American Hot Dip Galvanizers Association, Inc.	6
Anaconda Copper Mining Company	7
Bakelite Company, Division of Union Carbide and Carbon Corp.	111
Barrett Division, Allied Chemical and Dye Corp.	97
Brance-Krachy Co., Inc.	83
Carboline Company	93
Cathodic Protection Service	95
Coast Paint and Lacquer Company	73
Corrosion Engineering Directory	109
Corrosion Rectifying Co.	84
Corrosion Services, Inc.	98
Diamond Alkali Company	101
Dow Chemical Company	2
E. I. DuPont de Nemours & Co., Inc.	13
Duriron Co., Inc., The	Inside Back Cover
Federated Metals Division, American Smelting and Refining Co.	127
B. F. Goodrich Chemical Company	119
Harco Corporation	8
Haveg Corporation	9
Haynes Stellite Company, Division of Union Carbide & Carbon Corp.	14
Hercules Powder Company	129
Humble Oil and Refining Co.	71
Insul-Mastic Corp. of America	77
International Nickel Co., Inc., The	75
International Paint Co., Inc.	100
Johns-Manville Sales Corp.	91
M. W. Kellogg Co.	86
Koppers Company	78, 85
Mavor-Kelly Co.	106
Minnesota Mining & Mfg. Co.	12
Mutual Chemical Division, Allied Chemical & Dye Corp.	99
National Association of Corrosion Engineers	88, 96
National Carbon Co., Division of Union Carbide & Carbon Corp.	11
Nelson Electric Manufacturing Co.	103
Pipe Line Anode Corp.	102
Pipe Line Service Corporation	113
Pittsburgh Coke and Chemical Co.	Back Cover
Positions Wanted and Available	90
Prufcoat Laboratories	81
Resistoflex Corp.	123
Royston Laboratories Inc.	126
St. Joseph Lead Co.	121
Saran Lined Pipe Company	89
Schramm Fiberglass	6
Solvay Process Division, Allied Chemical & Dye Corp.	117
Standard Magnesium Corp.	116
Tapecoat Co., The	114
Tinker & Rasor	1
Tnemec Co., Inc.	103
Tretolite Company	107
Tube-Kote, Inc.	72
United Chromium, Inc.	15
United States Rubber Company	115
United States Stoneware Co.	125
Wholesale Coke Supply Co.	106
T. D. Williamson, Inc.	10

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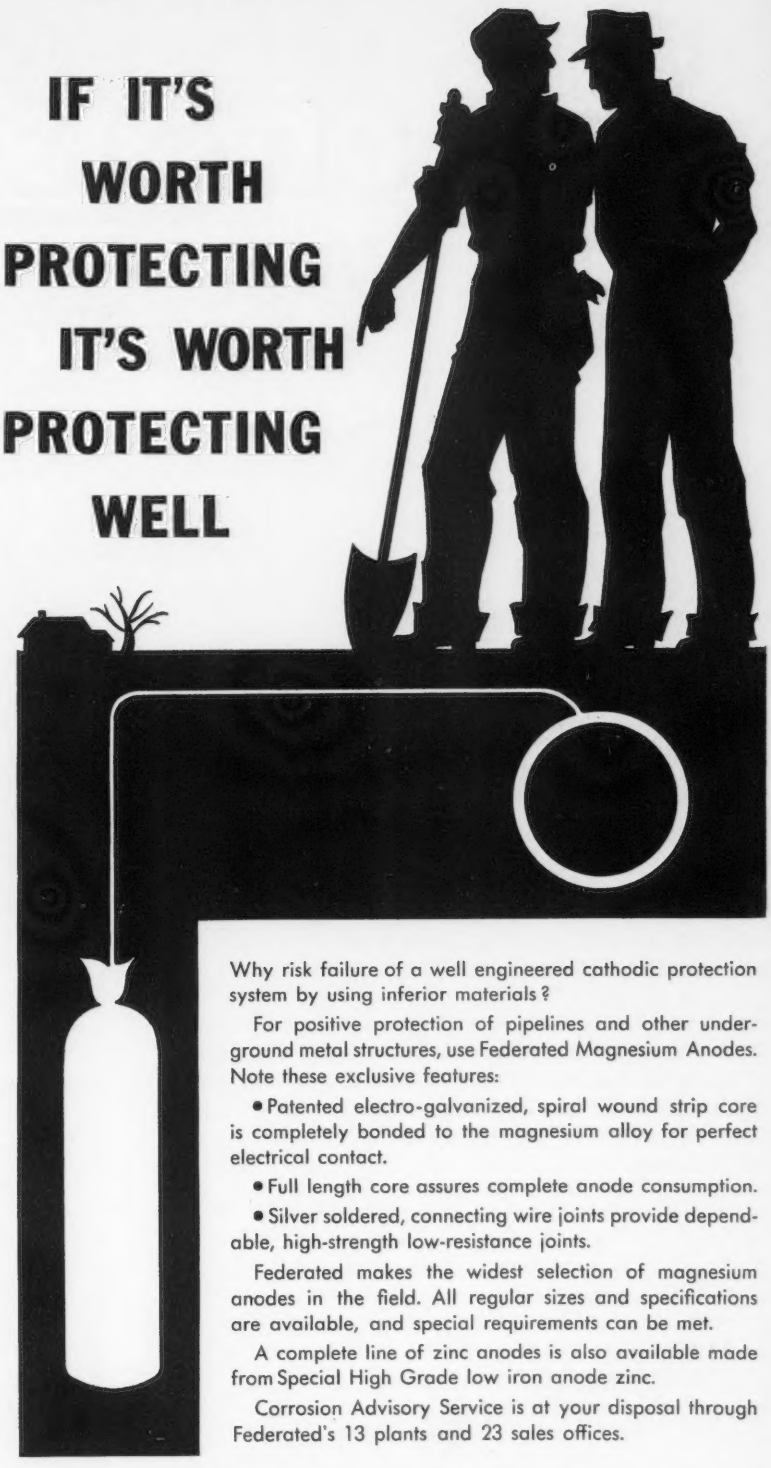

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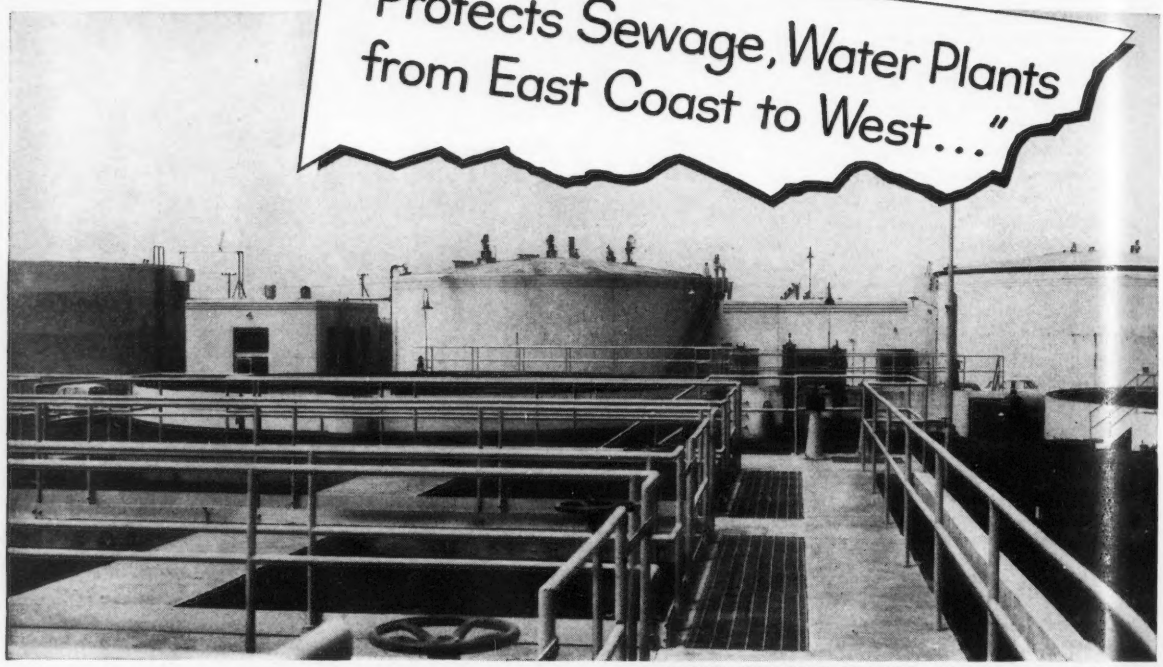

RESISTS HYDROGEN SULPHIDE—The digesters, clarifiers and control pump buildings at San Leandro, California Sewage Disposal Plant are protected with Ramuc masonry paint, a Parlon-based product of Inertol Co., Inc., Newark, New Jersey. After two year's exposure to sea, sewage fumes, and hydrogen sulphide fumes, the finish is still intact.

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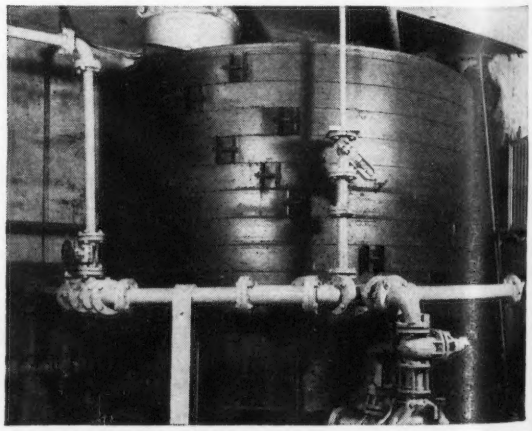

...AND FERRIC CHLORIDE—This 3,500 gal. ferric chloride storage tank in the vacuum filter plant, Back River Sewage Works, Baltimore, Maryland is covered with three coats of red Rubalt RA paint based on Parlon, manufactured by Alfred Hague & Company, Brooklyn, New York. Parlon finish was only one found able to resist corrosive effect of ferric chloride, which is so strong that it will eat away bare metal or concrete. Tanks are wood with rubber liner.

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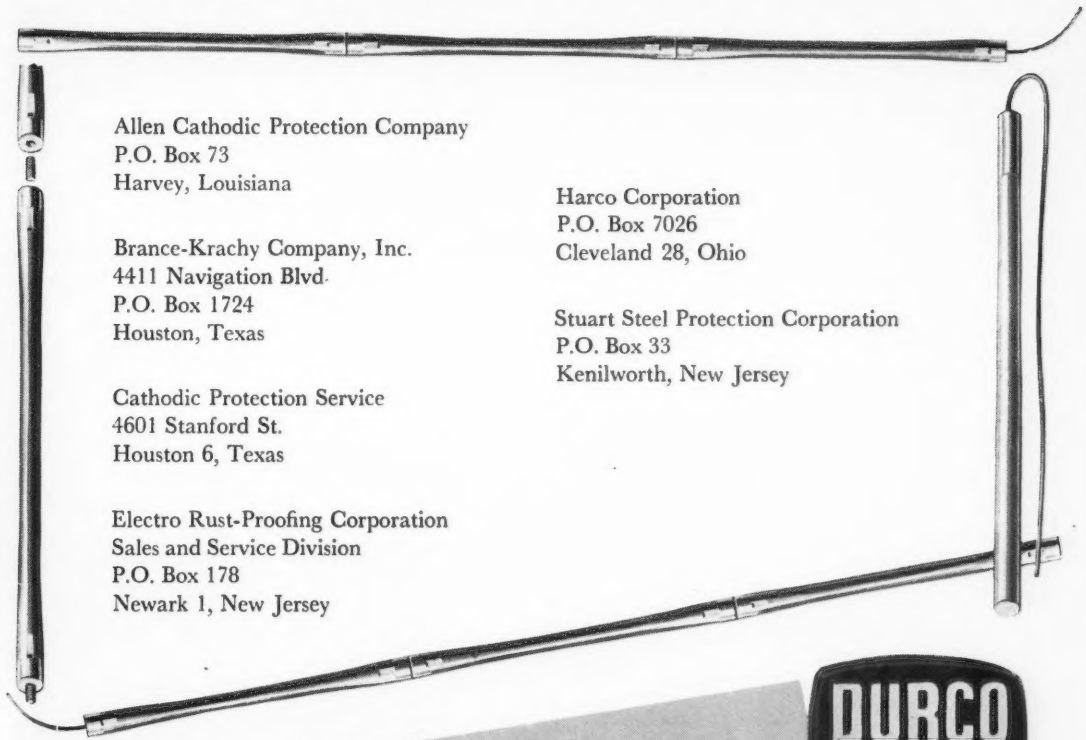

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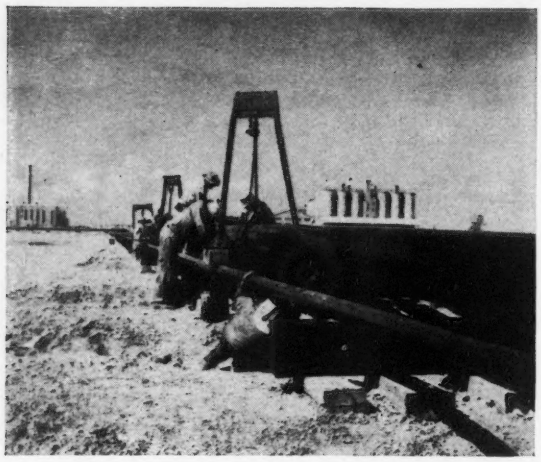

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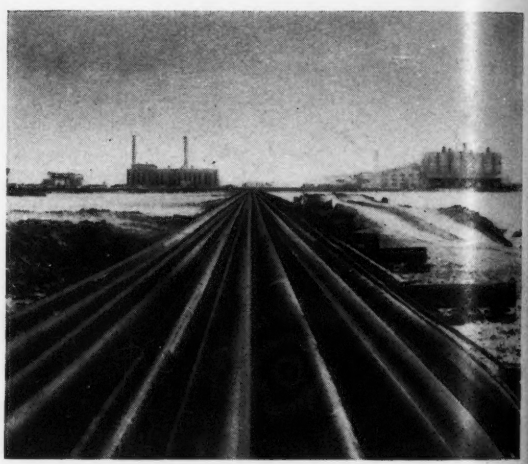

3. Pitt Chem 101 was economical to purchase and apply. It will protect this line against corrosion for years.

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